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ORIGINAL ARTICLES.

I.—On the Structure and Organisms of the Lower Limestone Shales, Carboniferous Limestone and Upper Limestones of the Forest of Dean.

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(PLATES XIV. & XV.)

SIR ANDREW RAMSAY has described[1] the Coal-fields of the Forest of Dean, Somersetshire, and Bristol as outliers of the great Coal-fields of South Wales; there is, however, a marked thinning out in the thickness of the Carboniferous rock in the Forest of Dean as compared with the development of those rocks in South Wales and Bristol. At Clifton, near Bristol, the total thickness of the Carboniferous Limestone is about 2900 feet, at the northern end of the Forest of Dean Coal-field it is about 600 feet.

Professor Edward Hull has given[2] a comprehensive idea of the several divisions of the Carboniferous series as represented by typical developments in England. He has divided the series into three divisions, which he has again subdivided into *stages* marked by letters. The following is Professor Hull's classification, but I have omitted details which do not concern this paper.

The British Carboniferous Series. Beds in Descending Order.

Essentially Freshwater and Estuarine Beds.	Stage G.	Upper Coal-Measures.
	Stage F.	Middle Coal-Measures.
Essentially Marine.	Stage E.	Gannister Beds (Phillips), or Lower Coal-measures.
	Stage D.	Millstone-grit Series. Coarse grits, flagstones, and shales, with a few thin coal-seams.
	Stage C.	Yoredale Series. Shales and grits, passing downwards into dark shales and earthy limestones.
Essentially Marine, except Stage A in Scotland.	Stage B.	Carboniferous Limestone. Massive Limestone, passing northwards into several beds, with intervening shales and grits.
	Stage A.	Lower Limestone Shales and Calciferous Sandstone. Dark shales in some places; grits, conglomerates, and red sandstones and shales in the northern district.
Freshwater Beds.	Base.	Upper Old Red Sandstone. Yellow sandstones and conglomerates.

In the Forest of Dean stage A is represented resting on a succession of many-coloured calciferous sandy beds and shales, very much

[1] Physical Geology and Geography of Great Britain, fifth edition, pp. 34, 35. Also, Mem. Geol. Survey, vol. i. p. 303.

[2] Quart. Journ. Geol. Soc. vol. xxxiii. p. 615, 1877.

like what Prof. Hull describes as occurring in "northern districts." They were first described by Mr. W. C. Lucy, F.G.S.,[1] and later on by myself.[2] Stage B is represented by the Carboniferous Limestone, or middle series, but appears to be quite void of fossil remains, which fact I shall refer to later on. Above stage B, Professor Hull gives, as stage C, the Yoredale Series, and he describes them as "shales and grits, passing downwards into dark shales and earthy limestones." In the Forest of Dean we have beds very similar in a lithological point of view to those which Prof. Hull described; but in my previous paper, just referred to, objection was taken to my classing these upper limestones as the representatives of the Yoredale Series. I shall not in this paper discuss that question, but I shall show that these upper limestones are different from the Carboniferous Limestone, and are quite as much entitled to be grouped separately as the Lower Limestone Shales. To condense what I have said, the Carboniferous Limestone series in the Forest of Dean consists of the following divisions:—

	Approximate thickness in feet.
Upper Limestones (occupying position of Yoredale Series of the North of England.) Stage C.	116 [3]
Carboniferous Limestone proper. Stage B.	360
Lower Limestone Shales. Stage A.	130

Lower Limestone Shales.

The calciferous sandy beds, which succeed Old Red Conglomerate, gradually become more calciferous in ascending order, till at last a series of quarries are found opened out in a succession of limestones and shales. Some of the latter are bituminous, a feature to which I have called attention in a paper communicated to the Cotteswold Club.[4] The lowest of these beds are exposed in two quarries on either side of the deep cutting near Drybrook, from which the following specimens were selected (see Plates XIV. and XV.).

No. 1 (Plate XIV. Fig. 1).—A crinoidal limestone which gave the following result on chemical analysis:—

Insoluble in acid	Insoluble residue (Sand)	3·68
	Organic matter	3·30
Soluble in acid	Carbonate of Lime...	90·40
	Carbonate of Magnesia	2·38
	Carbonate of Iron	·42
	Alkalies	trace
		100·18

The sand is little else than grains of quartz as large as ·01 of an inch in diameter, but average about ·003. The larger ones are rounded, the smaller ones angular. The absence of alumina in the analysis is a feature to be noticed, as in the analysis of a crinoidal

[1] Proc. Cotteswold Club, 1866.

[2] Quart. Journ. Geol. Soc. vol. xxxix. p. 212, 1883.

[3] I put the Upper Limestone at 116 feet, but it is impossible to measure the thickness accurately at present. The Wilderness Portland Cement Company, however, is making a cutting, near Mitcheldean, with the object of ascertaining the thickness, as the limestone produces a good cement.

[4] "On the Occurrence of Spores of Plants in the Lower Limestone Shales of the Forest of Dean," Proc. Cotteswold Club, 1883—1884, pp. 168—173.

limestone from the Lower Limestone Shales from Clifton the late Mr. Stoddart also called attention to the absence of alumina: he remarks,[1] "The absence of alumina in these beds is very remarkable, because the Lower Limestone Shales are very argillaceous." The organic remains preserved in this bed are chiefly those of Crinoids, associated with Polyzoa, the spines of *Spirifera* and *Productus*; in some layers the two latter are very numerous.

No. 2.—A light blue hard compact limestone, almost entirely made up of the valves of Ostracoda, but there are also present a few Polyzoa, the spines of Brachiopoda, and *Spirorbis carbonarius*. In the majority of cases the valves of the Ostracods are broken into fragments, but where preserved the largest measure ·035 of an inch in diameter. The remains are cemented together by crystalline calcite, and the empty valves are also filled with the same mineral.

No. 3.—A slightly ferruginous limestone. The organic remains are not well preserved; those which can be determined consist of joints of Crinoids, remains of Polyzoa, valves of Ostracods and obscure calcareous fragments.

No. 4.—A dark argillaceous bed containing 17·15 per cent. of organic matter, 6·89 of which was volatile. On washing a sample with distilled water, a large quantity of mud is got rid of, and the residue consists of quartz-grains, fragments of shells, plant-remains, and the jaws of Annelides.

No. 5.—A concretionary limestone slightly oolitic, the nuclei of the granules are grains of quartz. There are also present the valves of Ostracods, joints of Crinoids, and the remains of a small Coral.

The next specimens were selected from a quarry a little beyond the last in the direction of Mitcheldean, in which beds were exposed occupying a higher horizon than those in the previous quarry.

No. 6.—From a thickness of about 10 feet of thin strata, slightly ferruginous; on exposure to the air, the carbonate of iron (in which state the iron exists) undergoes decomposition, ferric oxide is formed which imparts a yellow tinge to the rock. The structure exhibited is chiefly that of calcareous sand, among the grains of which are fragments of shells. The spaces between the sand are filled in with calcite.

No. 7 (Pl. XIV. Fig. 3).—A bed of argillaceous limestone 3½ inches thick, and contains 11·15 of sand. It is made up of the valves of Ostracods, occasionally Polyzoa, scanty fragments of Crinoids, and oolitic granules. As in the previous examples, the limestone is consolidated by an infilling of calcite.

No. 8.—A dark argillaceous limestone 8½ inches thick, and containing 16·4 per cent. of sand. The calcareous constituents comprise the spines of *Spirifera*, broken valves of Ostracods, and other remains which are too obscure to be determined; some were probably decomposed and altered shell fragments.

No. 9.—Light brown arenaceous limestone, 6 inches thick, containing 37·2 per cent. of sand in quartz grains, measuring ·004 of an inch in diameter. Microscopic sections show the valves of Ostracods,

[1] Ann. Mag. Nat. Hist. vol. viii. 3rd series, p. 487.

numerous spines of *Spirifera*, fragments of shells, etc. The vacant spaces are filled in with calcite.

No. 10.—A bed of blue argillaceous limestone 6 inches thick; contains 16·75 per cent. of sand, the grains of which are rounded and measure about ·004 of an inch in diameter. The rock is chiefly made up of the spines and other remains of Brachiopoda and numerous valves of Ostracods.

No. 11.—A black argillaceous bed 5½ inches thick with calcareous arenaceous layers. In the argillaceous material the joints of Crinoids, remains of a small variety of *Rhynchonella pleurodon* and Ostracods were discovered. Sections of the thin calcareous layers showed them to be largely made up of the spines of *Spirifera*, a few joints of Crinoids, and calcareous fragments.

No. 12.—An earthy limestone 5 inches thick; contains 12 per cent. of sand, the grains of variable size, the largest measuring ·008 and the smallest ·002 of an inch in diameter. The limestone is largely made up of an organism to which I shall provisionally give the name of *Mitcheldeania* (Pl. XIV. Fig. 6), and which I shall describe further on. The rock also contains some Ostracoda.

No. 13 (Pl. XIV. Fig. 4).—A light limestone 8 inches thick, containing 3·2 per cent. of sand, the grains measuring ·003 of an inch in diameter. Flakes of mica and fragments of other minerals are also present. The bed contains the remains of *Mitcheldeania*, a few Polyzoa, a large proportion of Ostracoda, and a shell which Mr. Etheridge, F.R.S., tells me is allied to *Murchisonia angulata*.

Pl. XIV. Fig. 4 represents a portion of the rock in which the valves of Ostracods are the chief feature. The clear calcite is well shown filling up the empty valves and spaces between them.

No. 14.—Similar to the last, with the exception that *Mitcheldeania* is less numerous. Thickness 1 foot 6 inches.

No. 15 (Pl. XIV. Fig. 5).—Made up of various small concretions, of various shapes; calcareous fragments and occasional spines of *Spirifera*. Thickness 2½ inches.

No. 16.—A limestone 1 foot 3 inches thick. Chiefly concretionary, with the spines of *Productus*, Crinoidal remains, and other calcareous fragments.

No. 17.—A black argillaceous bed 4 inches thick, containing 5·13 per cent. of sand, the quartz grains measuring ·004 of an inch in diameter. Flakes of mica and fragments of other minerals also present.

No 18.—A light argillaceous limestone 7 inches thick, containing 16·5 per cent. of sand, the quartz-grains varying between ·009 and ·001 of an inch in diameter. The organic remains are chiefly those of Ostracods, well preserved and capable of being extracted from the matrix.

No. 19.—A shelly limestone 15 feet thick, and containing 39·2 per cent. of sand. The chief calcareous constituents are the remains of shells, and those in a very fragmentary condition.

General Review of the Lower Limestone Shales.

The samples examined are sufficient to give a correct idea of the

structure of the rock generally. In the lowest beds of the series Ostracods have contributed very largely, in some cases little else than the valves of these small Crustaceans make up the limestone. In the upper beds, with the exception of No. 16, they become less numerous, and in some cases are altogether absent.

Much the same may be said of the Crinoids. Though their remains occur throughout the series, they are most numerous in the lowest beds, and in one they are the chief factor, as in Fig. 1. The Polyzoa are most numerous in the Crinoidal bed, but are to be found throughout the Lower Limestone Shales. They are not, however, an important feature in the structure of the rocks with the exception stated. The shells of *Rhynchonella pleurodon* are very numerous in some beds of black shale, and on weathering taking place, they may be collected in hundreds. The Lower Limestone shales, as with limestones generally, represent the floor of a sea in which the organisms lived which we now find in a fossil state. By their death the limestone was formed from the calcareous portions of their structure. The deposition of the strata doubtless extended over a long period of time, during which the conditions were varied, and thus the life varied according as the conditions suited. For this reason we get limestones of different structure and quality, which, of course, was regulated by the organisms which contributed to their formation. The limestone-forming process was at times stayed, during which intervals clays and shales were deposited. The water was probably not deep. This is shown by the amount of sand in the limestone, and also by the great profusion of Ostracods, which class of Crustacea are not abundant in extreme depths of water.[1]

Organisms of the Lower Limestone Shales.

Ostracoda.—My specimens have been referred to Professor Rupert Jones, F.R.S., and Mr. J. W. Kirkby, to whom I am indebted for their careful examination. The following is a list of the genera and species which these gentlemen have been able to determine. Probably others exist, but the difficulty of separating them from the matrix, and thus obtaining reliable specimens, prevents a more definite statement being made.

Kirkbya variabilis, J. & K.
,, *plicata*, J. & K.
Cytherella extuberata, J. & K.
Bythocypris sublunata, J. & K.
Darwinala Berniciana (?), Jones.
Leperditia Okeni, Munster.

The above list is especially interesting and important in connection with the Ostracoda recently described[2] by Prof. Jones and Mr. Kirkby from the Gayton boring, Northamptonshire. The material examined yielded six recognizable forms, as follows:—

Kirkbya variabilis, J. & K.
,, *plicata*, J. & K.
Bythocypris sublunata, J. & K.
Macrocypris Jonesiana (?), K.
Cytherella extuberata, J. & K.
,, *attenuata*, J. & K.

Comparing the above list with mine, from the Forest of Dean, we find that from the Gayton boring six genera and species were determined, one of which was doubtful. In my list six genera and species

[1] Challenger Report, Zoology, on the Ostracoda, p. 1.
[2] Geol. Mag. 1886, Dec. III. Vol. III. pp. 248—253.

are also given, one of which, too, is doubtful. In each case we get five undoubted genera and species, and of these four appear in both lists. Mr. Kirkby writing to me remarks: "It is surprising how similar the groups of species are to those we have just described from the Gayton boring."

Professor Jones, after an examination of different samples from the same locality, makes similar remarks. Of the forms described from the Gayton boring three have not been known to occur above the Calciferous series of Scotland, which horizon is immediately above the Old Red Sandstone (Devonian). The forms referred to are *B. sublunata*, *C. extuberata*, and *C. attenuata*. Of these two appear in my list.

Crinoidea.—The Crinoidal remains in the Lower Limestone Shales appear to be those of two genera. One of these is *Poteriocrinus crassus*, Miller, and the other probably Miller's genus *Rhodocrinus*. In some of my slides apparent pentagonal joints are seen (Pl. XIV. Fig 2), which I was at first puzzled to account for. On reference to Miller's "Crinoidea," I found that he had figured[1] joints resembling mine, which were also collected in the Forest of Dean, and that he referred them to *Rhodocrinus verus*. Miller in his "Description" expresses some doubt as to whether all the forms referred by him to this genus are really the same species; he remarks: "In the columns (pl. ii. fig. 1, t. 22) which I consider as belonging to the animal of this genus, I have noticed two different modes of organization, which inclines me to suspect that although I am only able to treat of one species as decidedly ascertained, yet two distinct species may really exist. Thus in regard to the surface of adhesion, some columnar joints display numerous radiating striæ proceeding immediately from the alimentary canal to the circumference (figs. 6 to 10); other joints (figs. 1 to 5) have only a narrow striated rim with a smooth central area; and again some columns (figs. 11 to 15) are formed of joints of uniform thickness, from some of which, occasionally, several side-arms proceed; whilst other columns, particularly those from Mitcheldean, are formed of joints alternately thicker and thinner, smaller and larger, much contracted at their margin of mutual adhesion. In these every second or fourth joint is considerably thicker, showing at its circumference five or six tubercles, which render it angular and its surface waved, to which the joints above and below conform." It is therefore clear that Miller detected some points of difference in the specimens from the Forest of Dean compared with those from other localities. With regard to the striæ, I think he attaches too much importance to them; they are simply striations on the articular faces of the stem-joints, and the features pointed out by Miller are due to the particular portion preserved or examined. With regard to the joints themselves, these are features which are of importance, and though Miller only considered them of sufficient note to possibly justify a different species, it is probable that further investigation may prove that the fossil is wrongly referred to the genus *Rhodocrinus*. Having doubts regarding the specimens which I had collected, I sent them to Dr. P. Herbert Carpenter, F.R.S., and

[1] "Miller's Crinoidea," 1821, *Rhodocrinites*, plate 2, figs. 17, 18, 19, p. 107.

asked his opinion on them. He kindly wrote me as follows: "I think your pentagonal stem-joints may not improbably be identical with those figured by Miller on plate 2 of *Rhodocrinus*, figs. 17–22, but I have great doubts whether they can be properly referred to *Rhodocrinus*."

The microscopic section shown in Fig. 1 appears to throw some light upon the apparent pentagonal joints. The central object represents one of them surrounded by a circular margin. It is therefore possible that some of these Crinoids have a pentagonal centre, and that it is this central portion which is represented on Pl. XV. Fig. 12. I have shown my specimens to Mr. R. Etheridge, jun., who informs me that he has observed the same thing in some Crinoids which have come under his notice.

Polyzoa.—The specimens of Polyzoa were sent to Mr. John Young, Curator of the Hunterian Museum, Glasgow, who kindly examined them for me. Though the Polyzoa occur in such large numbers in the crinoidal bed, Mr. Young has only been able to detect two genera and species, namely, *Rhabdomeson* (*Millepora*) *gracile* (Phill.), and *Fenestella tuberculocarinata* (Etheridge, jun.).

Mitcheldeania Nicholsoni, gen. et. sp. nov. (Plate XIV. Fig. 6).—I have referred the specimens of this organism to Mr. John Young, Dr. Hinde, Professor Nicholson of Aberdeen, and to Mr. Robert Etheridge, jun., all of whom have kindly examined them, but are unable to recognize them as identical with any known form. I have, therefore, determined to describe and figure it as a new provisional genus under the name of *Mitcheldeania*, after the locality (Mitcheldean) near which I found it. To Professor Nicholson I am especially indebted for assistance in examining the fossil, but he is in no way committed to any of my remarks in reference to it. As a slight acknowledgment of Professor Nicholson's assistance and appreciation of his work generally, I propose to name the first species of the genus *Nicholsoni*. In working out this organism I have been placed at a disadvantage in not being able to separate reliable specimens from the matrix, on account of the nature of the rock in which the fossil occurs; the determination, therefore, has been chiefly arrived at from microscopic slides.

The organism, Fig. 6, consists of a series of concentrically arranged layers, or laminæ, penetrated by systems of tubuli which become more minute and numerous in the central series of laminæ. The tubuli are separated by the skeleton fibre, which is itself penetrated by a minute canal system. There are also other tubuli of larger size than are seen in the inner laminæ, which appear first in the third series, and become more numerous outwards. The skeleton fibre is also penetrated, in places, by centres of growth made up of concentrically arranged minute tubuli, resembling the series which constitute the nucleus of the entire organism. At the base there is a peduncle which probably served for attachment.

Conclusions.—*Mitcheldeania Nicholsoni*, then, was an organism the structure of which consisted of a series of concentrically arranged layers penetrated by two systems of tubuli, the larger measuring ·003 and the smaller ·001 of an inch in diameter. The latter were probably filled with living matter, and the larger I regard as zoöidal tubes. I

would refer this organism to the Hydractinidæ, and as allied to the Stromatoporoids. Professor Nicholson is himself struck with the similarity of the structure to certain Stromatoporoids, but remarks that he is not aware of any which have so minute a canal system of precisely the same nature; and that if it be referable to the Stromatoporoids, it would probably require to be placed in a new genus. Of course I am aware that Stromatoporoids have not before been noticed in Carboniferous rocks, but that is no reason why they should not occur.

In referring *Mitcheldeania Nicholsoni* to the Stromatoporoids, I do not wish to ignore certain features which this fossil possesses in common with some other Hydrozoa. Professor Nicholson called my attention to *Parkeria*, Carp., which no doubt shows structure which is also seen in *M. Nicholsoni*, but in the former there is a nucleus constituted of chambers which are laid end to end in a reticulate direction, and separated by septa. I have not detected a nucleus of this nature in *M. Nicholsoni*.

Another organism which especially struck Dr. Hinde as similar to my new genus is *Girvanella problematica*, Nich. and Ether., jun. Professor Nicholson has kindly sent me rock specimens containing that fossil, from which I have been enabled to get some good sections. As regards mode of occurrence, there is a great resemblance, and also in the concentric lamination, but the minute structure is quite different.

The Carboniferous Limestone—or Stage B of Prof. Hull—constitutes the middle division of the limestone series in the Forest of Dean. Commencing with the lowest beds, I have worked upwards, and in all that I have examined, the slides exhibit the same structure, namely, a rock made up apparently of very small calcareous granules (Pl. XV. Fig. 7). It is not, however, so formed; the key to the problem is Pl. XV. Fig. 8, in which we see the outlines of a previous structure, the whole having undergone complete change and been replaced by crystalline material. The granular appearance is due to the small crystals and possibly large ones which have cracked or split up into fragments. As to what the replacing mineral is, the following chemical analysis will enable us to judge. The sample was taken from the centre of the formation, and though one analysis cannot be said to prove the composition of the whole 360 feet of strata, yet I believe it to be typical of at least a large portion.

In making the analysis I was assisted by Mr. W. E. Wiltshire, F.C.S. As it is important, I will state it in two forms:

I.		II.	
Moisture	·02	Moisture...	·02
Organic matter...	6·17	Organic matter	6·17
Carbonic acid	44·01	Insoluble Residue	1·06
Insoluble Residue	1·06	Carbonate of Iron	1·01
Soluble Silica	·10	Soluble Silica	·10
Ferrous Oxide	·63	Carbonate of Lime	54·00
Lime	30·24	Carbonate of Magnesia... ...	37·19
Magnesia	17·50	Carbonate of Soda with trace of chlorine	·43
Soda	·25		
	99·98		99·98

The foregoing analysis shows the limestone to be dolomitized, the carbonate of magnesia being as high as 37 per cent. Of this I shall treat further under the head of chemistry.

The Upper Limestone Series.

This series consists of two varieties of limestone locally termed the "Crease" and "Whitehead." The former occupies the lower horizon of the two.

The Crease (Pl. XV. Fig. 9).—The samples which I have examined show an unusually coarse structure due to the size of the calcareous fragments of which the limestone is made up. The origin of these calcareous fragments is somewhat obscure, but I have detected among them undoubted remains of Crinoids. The grains are closely compressed, reminding one of the structure of arenaceous grits; the rock is, indeed, a calcareous grit.

The "Whitehead" Limestone.—The "Whitehead" follows the "Crease," and is represented by an interesting series of beds from which I have selected the following as typical.

No. 1 (Pl. XV. Fig. 11).—Oolitic limestone, from a thickness of about forty feet. The granules measuring from ·007 to ·018 of an inch in diameter. The nuclei are generally destroyed, leaving an open space. The spaces between the granules are often wide and are filled with calcite.

No. 2.—A concretionary limestone from a bed three feet thick. Contains the valves of Ostracoda, spines of *Productus* and angular grains of quartz. There are also present circular rings as large as ·005 of an inch in diameter, and are a conspicuous feature in the rock.

No. 3.—From a bed made up of concretionary nodules, as large as an inch in diameter, and calcareous sand. Microscopic sections of the nodules reveal the remains of a variety of organisms, but all badly preserved.

No. 4.—This is a very interesting bed, and makes a beautiful object under the microscope (Pl. XV. Fig. 12). The rock is made up of the remains of a spiral shell, of Foraminifera, Ostracoda, Polyzoa, and obscure calcareous fragments, the whole being cemented together by clear calcite.

No. 5 (Pl. XV. Fig. 10).—A peculiarly white limestone, which gave the following analysis:—

Insoluble residue (sand)	2·95
Organic matter	6·94
Water	1·40
Carbonate of Lime	85·56
Carbonate of Iron	·46
Soluble Silica	·01
Carbonate of Magnesia	·84
Alkalies	1·06
Phosphate and Sulphate of Lime, and loss	·78
	100·00

Sections of the limestone show it to be largely made up of the

remains of Ostracoda, among which Professor Jones has distinguished *Leperditia* and *Cytherella*, but as we have not been able to separate any from the matrix, the species have not been determined. In addition to Ostracoda, the rock contains remains of Foraminifera badly preserved, also occasional Polyzoa, and the spines (and possible shell fragments) of *Productus*.

General View of The Upper Limestones.

The beds of the Upper Limestones indicate a return of conditions not unlike those which existed at the time of the deposition of the Lower Limestone Shales. At the period of the latter, the Carboniferous Limestone was about to commence; at the period of the former, it was near to its close, and the great Coal epoch was soon to dawn. From what I have said respecting the changes which the beds of stage B, or the Carboniferous Limestone proper, have undergone, it is difficult to say what fossils they contained or what organisms contributed to the formation of the limestone; but in the Upper Limestones we get a return of life similar to that which contributed so largely to the Lower Limestones. I therefore contend that I am justified in forming a separate division of the Upper Limestones. If I am not, then there is no justification for making a separate division of the Lower Limestone Shales.

Chemistry.

As in the case of limestones generally, the Lower and Upper series have been consolidated by the deposition of calcite in the vacant spaces between the organisms and other calcareous fragments. With regard to the Carboniferous Limestone, that, too, undoubtedly originated from calcareous organisms, but a subsequent change occurred which replaced the original structure with magnesia and possibly some calcite. I am not aware that dolomitization in the Carboniferous rocks of the Forest of Dean has before been noticed, but it has in other localities. Mr. Sorby, F.R.S., states[1] that "in Derbyshire and elsewhere some of the beds are almost pure dolomite. As far as can be judged from their structure, they may have been normal limestones completely changed after deposition, and certainly do enclose dolomitized shells, Corals, and Encrinites." The late Professor Harkness called attention to the same thing in a paper[2] "On the Jointing in the Carboniferous and Devonian Rocks in the district around Cork and on the Dolomite of the same district." The limestone referred to by Professor Harkness has undergone considerable jointing, which he considered to be a factor in the process by which those particular beds became dolomitized. He says:[3] "The whole aspect of the Carboniferous dolomites of Cork and Kilkenny leads to the inference that certain changes have been effected on previously existing masses of carbonate of lime; and the general parallelism which occurs between these dolomites and

[1] Quart. Journ. Geol. Soc. Proc. 1879, vol. xxxv. p. 87.
[2] Quart. Journ. Geol. Soc. vol. xv. p. 86.
[3] Quart. Journ. Geol. Soc. vol. xv. p. 103.

the main joints, and also the intimate connexion which exists between them, supports the conclusion that the change was produced after the operation of those forces which gave rise to the phenomena of joints." Professor Harkness attributes the dolomitization to the sea-water finding its way into the joints and fissures of the limestone when submerged. In the case of the Forest of Dean, however, the amount of jointing would not be sufficient to produce such effects, in the presence of sea-water, as Professor Harkness speaks of in the district of Cork. That sea-water was the agent which supplied the magnesia I do not agree. Professor J. D. Dana states[1] that "analyses of the Coral Limestone of the elevated coral island Matea, by Professor B. Silliman, jun., have determined the singular fact that, although the Corals themselves contain very little carbonate of magnesia, magnesia is largely present in some specimens of the rock. It affords on analysis, 38·07 per cent. of carbonate of magnesia, and hence only 61·93 of carbonate of lime. . . . This introduction of magnesia into the consolidating submerged coral-sand or mud, has apparently taken place (1) in sea-water at the ordinary temperature; and (2) without the agency of any mineral waters except the ocean. But the sand or mud may have been that of a contracting and evaporating lagoon, in which the magnesia and other salts of the ocean were in a concentrated state." Looking at the fact that the Carboniferous Limestone in the Forest of Dean was undoubtedly originally formed by accumulations of the remains of organisms, seems to me to be against the lagoon theory. Had the strata been deposited under conditions of concentrating waters, I fail to see how the organisms could have lived in so briny a solution. In endeavouring to arrive at a solution of the problem, there are two details which must be considered. (1) The beds of the Carboniferous Limestone are not mixed with argillaceous strata; those of the Lower and Upper Limestone series are. (2) The proportion of insoluble residue (sand) in the Carboniferous Limestone is small. These two facts seem to indicate that either there was deep water at a distance from land, too far for much sediment to be carried, or else a lagoon existed. My objection to the lagoon theory has already been stated, and I think the evidence is in favour of deep water some distance from land. But in what way would this solve the problem of the formation of dolomite in the Carboniferous Limestone? We must consider the fact that in the Lower and Upper Limestones there are argillaceous beds; these latter are less numerous in the former than in the latter, and I am informed by Colchester Wemyss, Esq., J.P., that some of the beds contain a considerable proportion of magnesia. The effect of these argillaceous beds, it seems to me, would be to cover the limestone beneath with a water-tight stratum. This, however, was not so in the Carboniferous Limestone, and consequently the sea-water would have free course through the at first loosely accumulated calcareous remains. That dolomite might, under such circumstances, result from the decomposition of magnesium chloride, and possibly

[1] Corals and Coral Islands, 1872, pp. 356—357.

magnesium sulphate, we can readily understand. That dolomite can be produced by the decomposition of magnesian chloride in the presence of Iceland spar has been proved by Mr. Sorby, F.R.S.[1]

EXPLANATION OF PLATE XIV.

FIG. 1. Crinoidal Limestone, Lower Limestone Shales.
,, 2. Apparent pentagonal stem joint of a Crinoid, from the same bed as Fig. 1.
,, 3. Lower Limestone Shales, contains remains of Ostracoda, occasional Polyzoa, &c.
,, 4. Lower Limestone Shales, chiefly made up of the remains of Ostracoda. The infilling calcite in the spaces between the organisms is well illustrated in this specimen.
,, 5. Lower Limestone Shales, chiefly made up of minute calcareous fragments and concretions.
,, 6. *Mitcheldeania Nicholsoni.*

PLATE XV.

FIG. 7. Dolomitized Carboniferous Limestone.
,, 8. Dolomitized Carboniferous Limestone, the outlines of previous structure remaining.
,, 9. "Crease Limestone," base of Upper Limestone Series.
,, 10. "Whitehead Limestone," Upper Limestone Series, showing remains of Ostracoda and Polyzoa.
,, 11. Oolitic Limestone, Upper Limestone Series.
,, 12. Whitehead Limestone, another bed, showing remains of Ostracoda, spines of *Productus*, etc.

II.—On the Rocks surrounding the Warwickshire Coal-field, and on the Base of the Coal-measures.[2]

By Aubrey Strahan, M.A., F.G.S.,
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With Appendix I. on the Igneous Rocks of the Neighbourhood, by Frank Rutley, F.G.S. Appendix II. on the New Species *Olenus Nuneatonensis* and *Obolella granulata*, by G. Sharman.

(Communicated by permission of the Director-General.)

In a paper read before the Birmingham Philosophical Society in 1882, it was announced by Professor Lapworth that the discovery of fossils in some shales underlying the productive Coal-measures of Warwickshire, and coloured on the Geological Survey Map as Coal-measures, proved that these shales must be of Cambrian age (Lower Silurian of the Geological Survey).[3] As the true age of these shales had for many years been a debateable question, Professor Lapworth's discovery was of considerable interest, and has led to an important alteration being made in the map, the supposed Lower Coal-measures and Millstone Grit having both been now relegated to the Lower Silurian (Lingula Flags). It may be of interest, before entering on the description of these beds, to trace shortly the history of the error in their classification.

The first notice referring to the older rocks of Warwickshire that

[1] Quart. Journ. Geol. Soc. Proc. 1879, vol. xxxv. p. 73.
[2] Read before Section C. (Geology), British Association, Birmingham, Sept. 2, 1886.
[3] The nomenclature of the Geological Survey, according to which the Lingula Flags are included in the Lower Silurian, will be used throughout this paper.

appeared in the publications of the Geological Society is a paper on the occurrence of manganese near Hartshill.[1] The ore is described as occurring in detached pieces weighing from one to sixty pounds each, and distributed through a red clay, which chiefly forms the soil of the neighbourhood.

In 1822 the rocks in which the ore occurred were referred to as Coal-shale and Millstone Grit by Conybeare and Phillips.[2] In 1829 the Rev. James Yates[3] pointed out the resemblance of the Hartshill quartzite to that of Bromsgrove Lickey, and gave a most accurate account of the overlying shales and the intrusive character of the volcanic rocks, concluding that the quartzite and shales must be considered of Silurian age. In 1855 the Geological Survey Map (63 S.W.) was published, and was followed in 1859 by the Memoir on the Geology of the Warwickshire Coal-field, Sir R. Murchison being Director-General. In these publications the quartzite was referred to the Millstone Grit, and the overlying shales to a lower or unproductive subdivision of the Coal-measures. The reasons for which this classification was adopted are given on p. 8 of the Memoir. The quartzite "has an average dip to the south-west at an angle of from 30° to 40°, passing under the ordinary Coal-measures which lie conformably upon it. No fossils have ever been found in it, and from the strong resemblance it bears to the quartz-rock of Bromsgrove Lickey, it was formerly classed as part of the Silurian series; but from the fact of the complete conformity of the Coal-measures upon it, and the occasional streaks of Coal-measure-looking shale with which it is banded, the evidence is more in favour of its belonging to the Carboniferous formation." This conclusion was not arrived at without anxious deliberation. The late Prof. Jukes and Mr. Howell were in favour of retaining the beds in the Silurian series, while Sir A. Ramsay (at that time Local Director), in consideration of the perfect conformity between the quartzite and overlying shales, and of the *apparent* conformity between the shales and the productive Coal-measures, was of opinion that they must be included in the Carboniferous series. The views of Prof. Jukes are given in the Memoir on the South Staffordshire Coal-field (Memoirs of the Geological Survey), 2nd edition, 1859, p. 134. After speaking of the gentle westerly dip which the Silurian strata of the South Staffordshire Coal-field had assumed before the deposition of the Coal-measures, he continues: "That this gradual rise to the east was continued yet further in that direction beyond the bounds of our district is rendered probable by the fact of rocks still older than the Upper Silurian (perhaps older than any Silurian) appearing in the Warwickshire and Leicestershire coal-fields, with the Coal-measures resting directly upon them." Previously (pp. 80, 81, fig. 11), he

[1] Notice on the Black Oxide of Manganese of Warwickshire, by S. Parkes, Trans. Geol. Soc. series 2, vol. i. p. 168, 1824 (read 1821).

[2] Outlines of the Geology of England and Wales, by the Rev. W. D. Conybeare and W. Phillips, book iii. chap. iii. p. 406, and chap. v. p. 456.

[3] On the Structure of the Border Country of Salop and North Wales, etc., Trans. Geol. Soc. series 2, vol. ii. p. 237, 1829 (read in 1824).

had figured and described a section near Dudley, in which the Coal-measures were seen resting on Silurian shale, both being nearly horizontal, but the unconformity being shown by the fact of the Coal-measures abutting against a small cliff of Silurian shale at one part of the section. "From this very instructive instance we learn generally how, with perfect apparent local conformability, there may be still on the large scale a very great amount of unconformability between two formations." From these statements it is quite clear that Prof. Jukes had fully grasped the true relation borne by the Warwickshire quartzite and shales to the overlying Coal-measures.

In 1879, the results of a microscopic examination of the intrusive Diorites were described by Mr. Allport,[1] who accepted the conclusion of the Carboniferous age of the rocks, and it was not until the year 1882 that the discovery of fossils in the shales by Prof. Lapworth[2] finally disposed of the possibility of the beds being of Carboniferous age, and established the correctness of the earlier view that the quartzites with the overlying shales were of Silurian age. This being the case, it was evident that the base of the Coal-measures had yet to be found, and traced upon the map, and for the purpose of doing this I received instructions to proceed to the district in the spring of this year.

This task was rendered far easier than it would otherwise have been by Professor Lapworth's kindness in placing freely before me the results of his own observations on the Silurian rocks, and on their relations to a still older volcanic series beneath, one of the most valuable of these results being his discovery of fossils at different horizons, ranging from near the top to near the bottom of the shales. For the resemblance of the Silurian shales, and especially of some soft nearly black bands, to Coal-measures is so striking, that in the absence of such fossil evidence the difficulty of separating them would have been greatly increased. Not only are the Silurian shales entirely uncleaved, and, except in the immediate neighbourhood of the intrusive igneous rocks, very little altered, but their dip agrees very closely both in amount and direction with that of the Coal-measures, especially in the southern part of the district. The clue once provided, however, it became easy to see (1) that the conformability of the shales with the Coal-measures is apparent only, there being in reality such evidences of discordance as might be expected between rocks so very different in age; (2) that the Coal-measures are based by an impersistent bed of sandstone containing pebbles of quartzite and of the local rocks, bearing evidence (as in South Staffordshire) of having been deposited in the hollows of a floor of gently inclined Silurian strata; while (3) it became clear that the intrusive igneous rocks are entirely of

[1] On the Diorites of the Warwickshire Coal-field, Quart. Journ. Geol. Soc. vol. xxxv. p. 637, 1879.

[2] On the Discovery of Cambrian Rocks in the Neighbourhood of Birmingham, Geol. Mag. New Series, Dec. II. Vol. IX. p. 563, 1882 (reprinted from the Proc. Birmingham Phil. Soc. vol. iii. p. 234). See also Geol. Mag. New Series, Dec. III. Vol. III. p. 319, 1886.

pre-Carboniferous age, and do not affect the Coal-measures in any way whatever.

The total thickness of the Coal-measures, as now shown, amounts to between 600 and 700 feet, in place of about 3000, as previously.

It will be convenient in describing these rocks to take them in order of age, beginning with the southern end of the range of each formation.

The Caldecote Series.

The oldest rocks are found near Caldecote, rising from beneath the quartzite on the north-east side of the range of low hills, which this rock forms between Nuneaton and Hartshill. They are referred to by Professor Lapworth as the Caldecote Volcanic Series, and consist, as he pointed out to me, of a finely-laminated rock, probably a tuff, with intrusions of diabase and quartz-porphyry.[1] There are very few exposures of these beds. About a quarter of a mile east of Caldecote Windmill, there is an abandoned quarry known as the 'Blue Hole,' from which paving cubes were formerly obtained. The rock in request was the diabase, but the workings on the north side intersected quartz-porphyry, which had been intruded into, and contained fragments of, a highly altered fine-grained ash. The diabase with a sharply-defined line of separation is found in the side of the quarry above the quartz-porphyry. Its intrusion is considered by Professor Lapworth to have taken place subsequently to that of the quartz-porphyry.[2] The tuff has been found again by Professor Lapworth in the entrance to an old tunnel 100 yards west of Caldecote Hill, where the presumed bedding-planes have a dip 25° to 30° in the same direction as the quartzite, that is, about south-west. The further extension of these beds is inferred from the occurrence of fragments in the soil, and from the position of the overlying conglomerate, which will now be described.

The Hartshill Quartzite.

The Hartshill quartzite extends from the Midland Station at Nuneaton to half a mile north of Hartshill, with a steady dip to the south-west of from 25° to 45°. The whole series can be seen in the series of immense quarries in which it is worked for road-metal. The base of the quartzite is a coarse stratified conglomerate or breccia, containing fragments of the underlying Caldecote series, some of the fragments ranging up to the size of half a brick, as was pointed out to me by Prof. Lapworth. The base is seen in the cutting by which Boon's Quarry is entered, about one-third of a mile south-east of Caldecote Windmill. The quartzite becomes coarse in grain towards the base and passes into a grit made up of small rounded grains of

[1] These rocks were referred to by Sir Andrew Ramsay in his evidence given before the Coal Commissioners as being of doubtful origin (Report of Coal Commission, vol. ii. p. 470). Eventually from the limited nature of the exposures, and the small advance that petrography had made at the time of the publication of the map, they were included in the index with the intrusive diorites under the general name of greenstone.

[2] Geol. Mag. for 1886, p. 320.

quartz and other rocks. This grit rests on the greenish and purplish coarse conglomerate or breccia mentioned above. A better exposure of the lower beds is found in the entrance to a quarry half a mile south-east of Hartshill. There there occur in the quartzite thin bands of intrusive igneous rocks much decomposed. The lower beds of the quartzite consist of bands of conglomeratic grit, well bedded and split up with shaly partings, and strongly impregnated with manganese. The conglomerate is seen for a thickness of more than eight feet, but the actual base is not exposed. There are also a few conglomeratic bands higher up in the quartzite, with pebbles ranging up to half an inch in diameter.

I may remark here that the Blue Hole and both the sections in which the basement conglomerate is exposed have been opened since the original survey of this district was made, and that it was therefore almost impossible at that time to determine the nature of the rock beneath the quartzite, and its relation to this formation. The true nature of the Caldecote Series and of the basement conglomerate of the quartzite was first detected by Prof. Lapworth.

The great mass of quartzite overlying this basement conglomerate is an intensely hard fine-grained siliceous rock, in which the original sand-grains are so closely cemented together by silica as to have almost lost individuality. The rock, however, is well bedded, and contains thin bands of green or purplish shales. It is used most extensively for road-metal, and nearly the whole series of beds is exposed in one or other of the great quarries. The quartzite is also traversed by sheets of intrusive igneous rocks, ranging from 3 to over 100 feet in thickness, and following the bedding with remarkable regularity. The igneous rocks are usually quite decomposed to a depth of from 30 to 40 feet from the surface, especially when in thin beds. They are locally known among the quarrymen as "Dun Dick," and when sufficiently fresh are "cut" (broken to size) into paving cubes. The price of the quartzite road-metal is 3*s.* a ton when broken to size. I was informed that a prepared cubic inch of quartzite crushed at a pressure of 24,000 lbs. to the square inch, the igneous rocks yielding at between 11,000 and 12,000 lbs. to the square inch.

A good exposure of one of these intrusive sheets is found in the Midland Company's Quarry at Nuneaton Midland Station. The quarry is principally in this thick sheet, the eastern part only being in quartzite. The jointing of the igneous rock, which at a distance resembles bedding, is nearly at right angles to the bedding of the quartzite, that is, perpendicular to the plane along which the melted rock has been injected. In this quarry the basement-bed of the New Red Sandstone may be seen lying across the edges of the quartzite and igneous rock, as will be described subsequently. Another great sheet is seen in the cutting by which a quarry on the east side of the high road, one-third of a mile south of Caldecote Windmill, is entered, and again close to the windmill. This sheet forms the boundary up to which the old quarries along the road were worked. Most of the quarries now worked are in beds below this sheet.

The Stockingford Shales.

The shales which overlie the quartzite occupy a considerably larger area. They extend from a little south of Bedworth to Waste Hill, one mile and a half north-west of Atherstone, a total distance of nine miles and a half. They are divisible into two perfectly conformable subdivisions, the lower, which rests quite conformably on the quartzite, being distinguished by a bright red tinge and by the presence of minute Brachiopods of the genera *Lingulella* and *Obolella*, the upper consisting of olive-coloured, grey, and thin black shales, with *Agnostus* and *Olenus*.[1] The shales are fine-grained and laminated and contain only a few harder and more sandy micaceous bands. They are altogether uncleaved, and present so close a resemblance to Coal-measures, as to have led (in the absence of fossil evidence and in view of their apparent conformity with the productive measures) to their having been originally classed as Lower Coal-measures.

They are traversed by very numerous sheets of intrusive diorite, etc. These igneous rocks are frequently found to follow a bedding-plane for many yards, and on a general view indicate the strike of the shale very accurately. On a close examination it becomes evident that the shale overlying each sheet of igneous rock is as highly altered as that below, and that frequently the igneous rocks break obliquely across the beds, or even swell out into bosses, forcibly contorting and thrusting aside the surrounding shales. These facts, indicating the intrusive character of the rock, were clearly recognized by the Rev. J. Yates in the year 1824.

The southern termination of this range of Lower Silurian shales is concealed by Drift. But the beds seem to have been found in a colliery shaft at Hawkesbury Basin, one mile south of Bedworth, where the following section was proved:[2]—

		ft.	in.
Coal-measures.	Bind, rock, and fire-clay with coal and ironstone	182	11
	Black shale-rock		6
	White rock-binds	1	6
	Alternations of hard black bat and granite-like rock in boulders	172	9
		357	8

Mr. Howell remarks that the "granite-like rock" was not a granite, but that, not having seen it *in situ*, he is unable to say whether it is trap or an altered sedimentary rock. It seems extremely probable, however, that the rock described as hard black bat was the altered Lower Silurian shale, and the granite-like rock some of the dioritic intrusions which are so numerous in this part of the shale, as seen at Chilvers Coton.

The most southerly exposure is at Marston Jabet in the old quarry in diorite figured in the Memoir on p. 39, but the first surface

[1] This subdivision consists of two zones according to Prof. Lapworth, an upper zone characterized by *Sphærophthalmus alatus*, Beck., and a lower zone with *Agnostus sociale*, Tullberg. GEOL. MAG. for 1886, p. 321.

[2] The Geology of the Warwickshire Coal-field (Geol. Survey Memoir), p. 20.

evidence we get of the boundary between the Coal-measures and the Silurian shales occurs in the railway south-west of Griff Hollow. The bottom of the railway cutting is in white fireclay with nodules of clay-ironstone, while the wood on the east side is planted over old excavations in flaggy Silurian shales, lying on the top of the thick mass of diorite which is seen at the point where the road crosses the Griff Canal. The boundary of the Coal-measures is marked by a shallow "strike-valley," due to the comparative softness of the beds.

In the Chilvers Coton Railway-cutting we get a clear view of the Silurian shales, several intrusions of diorite, etc., and of the base of the Coal-measures. In walking from the station southwards we find first grey shales with a thin bed of diorite near the bridge. A few yards south of the bridge these shales pass under a thick mass of diorite, which extends to a distance of 150 yards south of the bridge; there its base is fully exposed. It rests upon shale dipping normally about west-south-west, but thrown into contortions immediately under the diorite. The base of the diorite is very straight and forms an angle of 25° with the horizontal. At first sight it resembles a fault of very low hade, but it seems on the whole more probable that its appearance is due to the diorite having broken through and across the shales at the time of its intrusion. Faults are rare in this neighbourhood, but evidences of the intrusive character of the diorite are abundant. The contortions of the shale moreover do not point to motion in any definite direction along the line of junction, but rather resemble the foldings produced in the leaves of a book by pressure straight upon their edges.

The shales which lie on the south side of this diorite have a steady dip to W. 10° S. of about 20°—30°. At 90 yards distance from their junction with the diorite just described, they are found to be split up by numerous strings and sheets of diorite and andesite, ranging from three inches to as many yards in thickness. These intrusive rocks, as is often the case, follow the bedding-planes very closely, so as to imitate contemporaneous lava-flows. But the alteration of the shale above, as well as below, the igneous rock is sufficiently marked to have determined the intrusive character of the diorite, without the conclusive evidence obtainable in other sections. The same shales occupy the cutting for a few yards further, until we are suddenly made aware of the fact that we have passed the boundary of the Coal-measures by the exposure of a seam of coal on the west side of the railway, as subsequently described.

The Coal-measures occupy the cutting to a distance of 130 yards south of the Accommodation Bridge, where the Silurian shales are brought to the surface again by a small fault. These shales dip to the north-east, and are highly altered by the influence of a sheet of diorite, which is seen in the cutting to rise from beneath them at 45 yards distance from the fault. The same sheet is well seen in a quarry behind Griff Hollow Farm, and in the high road close by. The diorites in this neighbourhood are much decomposed, and show spheroidal weathering even in the thinnest bands.

Another very admirable section has been opened in these rocks, in the Midland Railway between Nuneaton and Stockingford. The eastern end of the cutting is in red and grey or green shales, the red tinge being, as before mentioned, the predominating colour in the lower part of the Lower Silurian shales. The first sheet of diorite is met with a few yards east of the Accommodation Bridge. It is about 50 feet thick and contains a band of shale, 6 inches thick, about 3 feet from the top. This shale is of course highly altered, but the shale above and below the diorite has also been baked hard for a distance of about 6 or 8 feet. The top of the diorite is seen on the south side of the cutting and to the east of the bridge. On the west side of the bridge the overlying beds are seen to be pale grey shales with bands of black shale, the whole presenting an appearance very like that of Coal-measures. Further to the west the shales are seen to be traversed by numerous bands of diorite, etc., ranging from 1 to 8 feet in thickness, and in most cases following the bedding; but it may be noticed that some of the thicker beds thin out and reappear very suddenly, while on the south side of the cutting near the bridge, a sheet of diorite cuts across the beds of shale at an oblique angle. The western end of the cutting runs through pale fine shales with an occasional black band, or more sandy micaceous rocky bed. The dip increases westwards till the beds become nearly vertical.

The outcrop of the Lower Silurian shales throughout the northern part of the district ranges from one-half to one mile in width, and from the abundance of intrusive sheets and masses of diorite and other rocks, forms a prettily undulating country. The red beds which lie next above the quartzite can be well seen in Atherstone Outwoods; in a lane forming the south-east side of Purley Park; on the north side of Hartshill Heys; and near Hartshill. They are interstratified with pale grey or olive shales. The upper part of the shales are grey and contain dark, almost black, bands, and are well exposed at Oldbury Reservoir, in Monks Park, and in the Atherstone and Birmingham high road. The best section of the diorite is afforded by the great quarry at Oldbury Reservoir, where the whole thickness of a great sheet, with its junction with the shales above and below, is clearly seen. The description of this and of the other igneous rocks that have been referred to has been written by Mr. Rutley, and will be found at the end of this paper.

The following is a list of the fossils which were collected by Mr. Rhodes, fossil collector to the Survey, during the examination of this tract. Many of the best localities were pointed out to me by Professor Lapworth. The specimens have been identified by my colleague, Mr. G. Sharman.

Sponge spicules, *Protospongia fenestrata* ?, Salt.	Lane on S. side of Purley Park, 30 yards down. Grey shale. 1 specimen.
Pyritonema.	Lane on S. side of Purley Park, near top. Grey shale. 2 specimens.
Rod-like bodies, Annelids or Plants ?	Lane on S. side of Purley Park, near top. Grey shale. 1 specimen.

Rod-like bodies, Annelids or Plants?	Half a mile N.W. of Hartshill Castle. Red shale. 2 specimens.
,, ,, ,,	Atherstone Outwoods, 250 yards W.N.W. of Rawn Hill. Red shale. 15 specimens.
Annelid markings.	Griff Hollow Farm House. Grey shale. 1 specimen.
,, ,,	200 yards S.W. of Merevale Church. Grey shale. 3 specimens.
,, burrows and castings.	200 yards S.W. of Merevale Church. Grey shale. 11 specimens.
Dictyonema sociale, Salt.	200 yards S.W. of Merevale Church. Grey shale. 38 specimens.
Trilobites, fragments of.	200 yards W. of The Mawbournes. Grey shale. 3 specimens.
Agnostus, sp.	Road-cutting, $\frac{1}{4}$ mile S. of Chilvers Coton. Grey shale. 3 specimens.
,, *cyclopyge*?, Tullberg.	Junction of Griff and Coventry Canals. Grey shale. 2 specimens.
Olenus Nuneatonensis, Shar.	W. end of Midland Railway cutting. Grey shale. 32 specimens.
,, sp.	W. side of Railway cutting, 300 yards S. of Chilvers Coton Station. Grey shale. 1 sp.
,, *Salteri*?, Call.	W. end of Midland Railway cutting. Grey shale. 2 specimens.
Lingula lepis ?, Salt.	Marston Jabet. Red shale. 7 specimens.
Lingulella Nicholsoni, Call.	200 yards W. of The Mawbournes. Grey shale. 2 specimens.
,, ,,	Lane on S. side of Purley Park, 30 yards down. Black shale. 47 specimens.
,, ,,	Lane on S. side of Purley Park, 50 yards down. Red shale. 1 specimen.
,, ,,	Atherstone Outwoods, $\frac{1}{4}$ mile S.W. of Rawn Hill. Red shale. 8 specimens.
Obolella granulata, Shar.	Lane on S. side of Purley Park, near foot of hill. Red shale. 2 specimens.
,, *Sabrinæ*?	Lane on S. side of Purley Park, near top. Grey shale. 3 specimens.
Theca, sp.	200 yards S.W. of Merevale Church. Grey shale. 2 specimens.

This list may be supplemented from the following specimens which have been collected from the Stockingford Shales by Professor Lapworth, and identified by himself.[1]

1. Purple and green shales.

Obolella sagittalis, Salt.
,, *Salteri*, Holl.
Orthis lenticularis, Wahl.
? Lingulella pygmea, Salt.
Protospongia fenestrata, Hicks.
Serpulites fistula, Holl.

2. Black and grey shales.

(*a*) Lower zones.

Agnostus pisiformis (*princeps*, Salt.).
Agnostus pisiformis, var. *sociale*, Tullberg.
Beyrichia Angelini, Barr.
Leperditia sociale, Brögger.
Lingulella Nicholsoni, Call.

(*b*) Upper zones.

Sphærophthalmus alatus, Bœck (*S. humilis*, Phill.).
,, *? flagellifer*, Angelin.
Agnostus cyclopyge?, Tullberg.
? Dictyonema.
? Hymenocaris.

Nearly all these fossils occur in some part or other of the Lingula Flags. *Protospongia fenestrata*, Salt., occurs in the Harlech Beds, and

[1] This list was furnished to me in MS. by the kindness of Prof. Lapworth. He remarks that *Obolella sagittalis*, *Lingulella pygmea*, and *L. Nicholsoni*, may be all of them varieties of *L. lepis*.

in the Menevian of South Wales (Mem. Geol. Surv. vol. iii. p. 472). *Dictyonema sociale*, Salt., is found in the uppermost Lingula Flags in North Wales (*ib.* p. 536), in the Shineton Shales (Tremadoc) in Shropshire, and at Malvern (Quart. Journ. Geol. Soc. vol. xxxiii.). *Agnostus princeps*, Salt., occurs in the Upper Lingula Flags, and Tremadoc Slate of North Wales, and in the Lingula Flags of South Wales (Mem. Geol. Surv. vol. iii. p. 489), and *Olenus Salteri*, Call., is common in the Shineton Shales of South Shropshire (Quart. Journ. Geol. Soc. vol. xxxiii. p. 666). *Lingula lepis*, Salt., ranges from the Lower Lingula Flags to the Arenig (Mem. Geol. Surv. vol. iii. p. 538), but is commonest in the Tremadoc. *Lingulella Nicholsoni*, Call., and *Obollela Sabrinæ*, Call., are common in the Shineton Shales (Quart. Journ. Geol. Soc. vol. xxxiii.).

In Professor Lapworth's list we find the following additional forms: *Obolella sagittalis*, Salt., which occurs in the Menevian of North and South Wales; *O. Salteri*, Holl, known in the Upper Lingula Beds of Malvern; *Orthis lenticularis*, Wahl., which occurs in the Upper Lingula Flags (Dolgelly group of Belt); *Lingulella pygmea*, Salt., of the Upper Lingula Flags; *Serpulites fistula*, Holl, from the same beds near Malvern; *Sphærophthalmus* (*Olenus*) *alatus*, Bœck, of the Upper Lingula Flags, and the black shales of Malvern; *S. flagellifer*, Angelin, which occurs in the Lingula Flags, and is believed to range up into the Tremadoc.

It may be concluded that the Stockingford Shales belong to a late Lingula Flag age, including possibly a portion of the Lower Tremadoc series.

The base of the Coal-measures.

The most southerly point at which the position of the base of the Coal-measures has been definitely fixed is the colliery at Hawkesbury Basin, previously alluded to. There the Silurian rocks (presumably) were entered at a depth of 115 feet 5 inches below the Bench Coal, the lowest seam worked in this coal-field. We next find evidence of its position in the railway-cutting near Griff Hollow, as has been described. But in the cutting at Chilvers Coton the junction is fully exposed to view. A coal-seam is seen on the west side of the cutting 116 yards north of the Accommodation Bridge (the second bridge south of Chilvers Coton). This seam is underlain by three feet of white fireclay, which rests upon about eight inches of sandstone. On clearing the soil from the base of this sandstone, it may be seen that it rests upon soft blue laminated shale, weathering yellow, and obviously forming part of the same set of shales in which the intruded diorites described above occur. The dip of the Coal-measures is nearly in the same direction as that of the shales, but is less rapid, so that by clearing a sufficient length of junction it may be seen that there is an actual unconformity. The Coal-measures occupy the cutting to a distance of 130 yards south of the Accommodation Bridge, where the Lower Silurian shales are brought up again by a small fault running about S. 35° E., the evidence for the fault being the fact that the dip of the Coal-measures continues

to be southerly, that is, towards the Silurian shales, close up to the point where these shales reappear. This point is marked by slips in both sides of the cutting, necessitating the covering up of the side-drains.

From Chilvers Coton northwards there is no section showing the base of the Coal-measures for nearly four miles, but its position is indicated by the rise of the ground, where the harder Silurian shales with the intruded diorites rise to the surface. There can be little doubt that the Coal-measures rest almost directly upon the highest beds seen in the Midland Railway cutting near Stockingford, for it is known that the workable coal-seams crop out in the depression which lies at the west end of the cutting. They are not exposed, but two or three hundred yards south of the Accommodation Bridge there is an old pit, now ploughed over, in which fragments of soft Carboniferous sandstone occur, and which probably marks the position of the boundary of these beds. On following the boundary northwards, we find it marked by the outcrop of a seam of coal in the bed of the stream west of Camp Hill, the hill itself consisting of the shale with diorites, etc., seen in the western part of the railway cutting. The coal-seams, which have been for the last two miles resting close upon the Silurian shales, now begin to be separated from them by beds which thicken steadily northwards. The nature of these beds is first seen near Oldbury Hall. A pebbly sandstone dipping gently to the west, and resting with a marked unconformity on the Silurian shales, may be traced continuously from here to the Atherstone and Birmingham high road. The rock is seen in the sides of a pond at Oldbury (Farm); in the foundations of the farm west of Hopwood Coal Wood; in a sandpit near The Mawbournes; and in some old quarries 200 or 300 yards further west in the edge of the wood. The rock is buff-coloured or white, and so soft as to be readily broken down into sand by the use of a pick. It is associated with some mottled red and white clays, which are exposed in the brook near the south-west corner of Hopwood Coal Wood, and were found in laying the pipes of the Atherstone Waterworks along the lane which passes the sand-pit. The red tinge, however, is not confined to the lowest beds of the Coal-measures, but may be seen in many of the fireclays associated with the workable coal-seams. The sandstone is seen again in the north part of Monks Wood in an old pit close to a small quarry in diorite and Silurian shale, and again in the side of the bridle-path leading into the high road, but from this point northwards the beds which underlie the coal-seams rapidly disappear, until the seams come down, as at Stockingford, close on top of the Silurian shales.

The unconformity between the Coal-measures and the Lower Silurian shales, which is generally masked on this side of the Coalfield from the accidental parallelism between the bedding of the two formations, is here very marked. The dip of the Coal-measures is slight, ranging from 6° to 8°, while that of the Silurian shales ranges from 20° to 40°. As a consequence of this the Coal-measures, where they extend eastwards, at Mawbournes, overlap a great thickness of

the shales, including two sheets of igneous rock. The Pre-Carboniferous age of the igneous intrusions, which might have been inferred from their absence in the Carboniferous rocks and abundance in the Lower Silurian shales, is thus placed beyond doubt.

On passing Merevale the lower beds of the Coal-measures again thicken out rapidly, with the development of a pebbly sandstone at the base as before. The best section of this basement bed is found in the Baddesley Mineral Railway, but it may be traced from Merevale Brook to a little north of Waste Hill.

Dosthill.

While Professor Lapworth was investigating the neighbourhood of Nuneaton and Atherstone, the igneous rocks of Dosthill, on the opposite side of the Coal-field, were visited by Mr. W. J. Harrison, F.G.S., with the result of finding that shales similar to those of Atherstone occurred here also.[1] The shales are first seen where the footpath to Dosthill intersects the road to the Ford. They are immediately overlain by a pebbly sandstone which forms the base of the Coal-measures, and which may be traced southwards along the west side of the lane, through the churchyard and neighbouring farm-buildings. Immediately to the south of the village this sandstone thins rapidly out, and the coal-seams come nearly, if not quite, into contact with the diorite. But after passing the most southerly of the igneous rocks, this sandstone reappears. There is no good section in it, but its course can be followed without difficulty across the ploughed land.

The shales are seen in the side of the high road a quarter of a mile south of Dosthill; in a small pit near Stockall Barn; in the side of the high road again near the word 'mill'; and lastly in the brook which comes down from the Brick Works.[2] The dip is in all cases towards the south-west, at angles varying from 20° to 40°, and therefore in nearly the same direction as on the east side of the Coal-field. The dip of the Coal-measures, on the other hand, is towards the east, and generally at a high angle (from 50° to 80°), so that the unconformity is most conspicuous. The shales are highly altered grey and olive-coloured sandstones. No red beds are seen, and at present no fossils except worm-tracks[3] have been found. There is a strong resemblance, however, in these shales to the Nuneaton and Atherstone beds, and there can be little doubt that they also are of Lower Silurian age.

The Base of the Coal-measures continued.

The nature of the evidence, on which the base of the Coal-measures has been drawn upon the map (now for the first time), has been given above. It has been shown that the actual base is formed in some cases of a conglomeratic sandstone, with a considerable

[1] Geol. Mag. 1882, New Series, Dec. II. Vol. IX. p. 565.

[2] The position of the boundary fault of the New Red Marl is marked in this brook by a rubble of diorite resting against red and white clay. Lumps of a white siliceous vein-stuff containing specks of galena may be picked out of the white clay.

[3] Harrison, Midland Naturalist, vol. viii. 1885.

thickness of strata intervening between the coal-seams and the Silurian platform, while in others the coal-seams appear to rest almost directly upon this platform. The impersistency of these lower beds led Professor Lapworth to conclude that the Stockingford shales were brought "in a long-curved strike fault against the Coal-bearing beds of the Upper Carboniferous."[1] The same view was taken by Mr. Harrison also, who writes that the line of fault between the Coal-measures and the Stockingford Shales is "marked by a line of brick-pits in which the rubbed-up material or 'fault-stuff' is worked," and again, in reference to Dosthill, that "on the west of the hill . . . . a line of fault runs, by which the Triassic strata are placed on a level with the Cambrian shales, while on the eastern side a parallel fault of less 'throw' places the Coal-measures in a similar position."[2]

The mapping of the boundary, however, about Oldbury, placed it beyond doubt that in this neighbourhood it was not a fault, but an unconformable superposition of the one series upon the other, while the section at Chilvers Coton proves that the absence of the conglomeratic sandstone is due to attenuation and does not imply a fault. Nor in the intermediate ground is there any reason to attribute the varying distance of the seams from the top of the Silurian rocks to a fault rather than to the known variability of the lower beds of the Coal-measures, the material referred to by Mr. Harrison as 'fault-stuff' being merely such fireclays and shales as are commonly found in connection with seams of coal in the Coal-measures. The relations of the Coal-measures to the Silurian platform appear to be exactly paralleled by those of the Coal-measures of South Staffordshire to the platform of the Upper Silurian rocks, on which they rest in that county. Professor Jukes writes[3] that "the Silurian rocks were greatly denuded and worn away, and cliffs and hollows formed in them, on, against, and over which the Coal-measures were deposited, both lying in a nearly horizontal position" (p. 81); and again, "We have already, in examining the base of the Coal-measures, seen the way in which at particular spots the lower beds of that formation filled up hollows in the Silurian rocks and obliterated their little pre-existing cliffs, and thus formed a smooth floor for the deposition of the chief mass of the Coal-measure beds" (p. 135).

These words describe exactly the manner in which the earlier beds of the Coal-measures appear to have been laid down in Warwickshire. We have here a platform of rocks varying in hardness, and forming in consequence such peculiarly undulating ground as is found near Merevale. At the commencement of the Carboniferous period they must have presented just such a surface for the reception of the first deposited sediments, the igneous rocks standing up, as now, in small hills above the general level of the shales, and it seems to have resulted from this that a thick mass of

[1] Geol. Mag. Dec. II. Vol. IX. p. 565.
[2] Midland Naturalist, vol. viii. p. 72, 1885.
[3] The South Staffordshire Coal-field (Memoirs of the Geological Survey), second edition, 1859.

sandstones and clays was deposited at Oldbury and Waste Hill, while the bosses of diorite, etc., about Merevale remained still uncovered. Similarly, at Dosthill the diorite seems to have formed a small elevated area, bare of sediment, while conglomeratic sandstone was being deposited on its flanks.

The Base of the New Red Sandstone.

From the south end of the Warwickshire Coal-field northwards to Nuneaton, the New Red Sandstone (Waterstones) rests unconformably, first on Coal-measures, then on the Silurian shales and diorites, the junction being exposed in an old quarry at Marston Jabet,[1] and in Wash Lane, Nuneaton. In both cases soft red and white sandstone, based by an inch or two of breccia, is seen resting on diorite and shale. The same boundary-line is seen again in the Midland Co.'s Quarry near Nuneaton Station (Midland Railway). The beds, which are flaggy and resemble parts of the New Red Marl (into which the Waterstones shade insensibly), are seen resting on a very uneven floor composed in part of a sheet of igneous rock, and in part of quartzite. The hollows in this floor are filled with a breccia of large fragments of quartzite, sometimes a foot across, while three or four feet from the bottom of the red beds there is seen a conglomeratic band containing well-rounded pebbles of quartzite, from $\frac{1}{2}$ to 1 inch in diameter.

From this point northwards, however, the boundary of the Trias is shown as a fault. The evidence of this is given by Mr. Howell as follows.[2] The coals were wrought in the old workings near Polesworth Station up to a "Red Rock Fault" and there entirely cut off. Near Dordon the coals were found to be so much faulted that the workings were not proceeded with. Lastly, a fault falling into the same line is seen in a quarry in Merevale Park (p. 50). The absence of the Lower Keuper Sandstone (Waterstones) between Atherstone and Nuneaton is also taken as evidence of a fault, and it may be added that the nearly straight course taken by the boundary is in a general way suggestive of a fault rather than of a natural superposition. The existence of such a fault, however, has been questioned by Mr. W. Andrews,[3] and borings made since the date of the original survey of the ground have proved that the fault, if it exists, has not the importance which might have been attributed to it. For it might have been supposed that the Coal-measures would occur beneath the Red Marl on the east side of the fault, having been thrown down

[1] Geology of the Warwickshire Coal-field (Memoirs of the Geological Survey), p. 39, fig. 4.

[2] Geology of the Warwickshire Coal-field.

[3] In a paper read at the Annual Meeting of the Warwickshire Naturalists' and Archæologists' Field Club, 1884. A different view was taken by Prof. J. Phillips, who refers to the "curious circumstance, that the Nuneaton coal-field terminates on the north-eastern [side] by a magnificent line of fault. It is one of the grandest lines of fault which can be seen anywhere, and along that line of fault there are the effects of metamorphosis; there are considerable bursts of trap-rock" (Coal Commission Report, 1871, vol. ii. p. 494). The trap-rock referred to appears to be the Caldecote Volcanic Series, which is of course of vastly greater antiquity than the fault.

with this rock against the older Palæozoic strata. The absence of Waterstones, moreover, does not necessarily imply the presence of a fault, for these beds constitute merely the earlier and more sandy sediments of the New Red Marl, and are known to be quite unrepresented in some other localities where the Red Marl mantles round bosses of old rock, as at Croft, Sapcote, etc.

That there is a fault, however, along the northern part of the coal-field appears to have been proved, and that it extends southwards as far as shown, though perhaps with no great throw, seems probable. Near Hartshill Wharf is a quarry in quartzite in which the base of the Trias is seen, the lower beds consisting of about three feet of sandstone, overlain by about three feet of marl, and lying upon the quartzite. The beds undulate and when last seen are dipping steeply, as though near a fault. If there is a fault here, the Triassic beds seen must be on the west or upthrow side. The section proves therefore that the Trias rests upon the quartzite here, without any of the Coal-measures intervening.

At the brick-pit near the canal by Nuneaton Midland Station, the Red Marls are seen with a dip ranging up to 35°. The quartzite rises to the surface close by, but the junction is not exposed. The steepness of the dip of the Marl, however, points to the boundary being probably a fault.

We have, then, four instances in which the Trias is seen resting directly upon the Silurian rocks, namely, Marston Jabet, Wash Lane, the Midland Co.'s quarry, and Hartshill Wharf. This evidence alone would have been sufficient to indicate that the Trias of the great plain on the north-east of the Warwickshire Coal-field would probably be found to rest in great part on the older Palæozoic rocks, and not on Coal-measures, especially when it is remembered that the nearest exposure of Palæozoic rock to the east (namely, at Sapcote) shows syenite rising through the Marl. But this conclusion has been placed beyond doubt by the results of borings, some of which have reached the base of the Triassic rocks, and proved the depth to the Palæozoic floor. The following is a list of those which bear upon the district under consideration.

Hawkesbury Pumping Station; about five miles south of Nuneaton. 252 feet above Ordnance Datum.[1]

Drift	30 feet.
Lower Keuper Sandstone [Waterstones]	90 ,, [1]
	120 ,,

The White Stone, about 2½ miles south-east of Nuneaton. A well to a depth of 80 feet, a borehole to a further depth of 50 feet. Height above Ordnance Datum about 250 feet.[2]

White sandstone and red shale [Waterstones]	60 feet.
Hard mottled blue and purple shales	70 ,, [1]
	130 ,,

[1] Report of the British Association for 1875 (Report of the Committee on the Circulation of Underground Waters), pp. 135, 136. For the Nuneaton boring see also Report for 1878, Report on the Circulation of Underground Waters, p. 7.

[2] The details of this section were given me by Mr. W. Andrews. The Waterstones are well exposed in a quarry by the side of the L. and N. W. Railway, near Attleborough.

At the time of my visit, April, 1886, the débris from the pit was in a fresh condition. The character of the shales left no doubt that they were of Silurian age, and probably of the same age as those that crop out at Marston Jabet. Some of the fragments were intersected by veins of gypsum, doubtless derived by infiltration from the Trias above. No fossils have been found.

NUNEATON: centre of the town. 210 feet above Ordnance Datum.[1]

Drift (sand, gravel, and clay)	18	feet.
Red Marl	12	,,
Lower Keuper Sandstone [Waterstones]	80	,,
Hard slaty white rock [probably Hartshill Quartzite]	2	,,
	112	,,

LINDLEY HALL ESTATE; boring near the Fenn Lanes. About three miles north of Nuneaton.

Soil, red clay, etc., (Drift)	6	feet.
Red marl with red and blue rock and gypsum	456	,,
Blue, red, and brown rock with marl, probably Waterstones	181	,,[1]
	643	,,

HINCKLEY WHARF, about three miles east-north-east of Nuneaton, 313 feet above Ordnance Datum.[1]

Glacial Drift	Sands and Boulder-clay	88	feet.
Red Marls	Red gypseous marls with bands of grey sandstone	408	,,
Waterstones	Red, grey, and brown sandstones with bands of marl	209	,,[1]
		705	,,

This boring is nearly midway between the exposures of Palæozoic rocks at Nuneaton and Sapcote, and is probably near the deepest part of the trough of Triassic rocks separating these localities. It shows that the lower sandy beds of the Red Marls, which are distinguished by the name of the Waterstones, increase rapidly in thickness on receding from the old land-barriers or islands, formed by the harder parts of the Silurian and pre-Silurian series. In this they may be compared to the impersistent sandy and conglomeratic beds which form the base of the Coal-measures, as previously described.

HINCKLEY; at the Holy Well, 330 feet above Ordnance Datum [should be 421].[2]

Drift (pebbly clay, sand, and gravel)	150	feet.
Red marl	20	,,
Lower Keuper Sandstone (viz. *thin* beds of clay and gypsum alternating with *thick* beds of red, grey, and white sandstone) [Waterstones]	370	,,
	540	,,

[1] Report of the British Association for 1882. Report on the Circulation of Underground Waters, pp. 14, 15, where the section is given in full.

[2] Report of the British Association for 1875 (Report of the Committee on the Circulation of Underground Waters), pp. 136, 137. For a further account of the Hinckley Boring see Report for 1879, p. 160.

Elmesthorpe Boring, at Sapcote Freeholt, two miles east of Hinckley and two miles west of the syenite boss of Sapcote. 300 feet above Ordnance Datum.[1]

Drift	10 feet.
Red Marl	120 ,,
Lower Keuper Sandstone [Waterstones]	330 ,,
Slaty rocks with a dip of 70°, Lower Silurian ?	980 ,,
	1440

This boring appears to have subsequently reached a depth of 1655 feet from the surface without meeting any change of ground.

Lindridge Colliery Company (Landridge ?), one mile north of Desford. 400 feet above Ordnance Datum.[2]

Drift	2 feet.
Upper Keuper Sandstone	20 ,,
Red Marl (marl with thin bands of gypsum)	44 ,,
Lower Keuper Sandstone. Waterstones	204 ,,
	270 ,,

Newton Unthank, near Desford Station. One mile and a quarter E.S.E. of the Lindridge section, 320 feet above Ordnance Datum.[3]

Drift	6 feet.
Upper Keuper Sandstone and Marls	56 ,,
Red Marls with sandstone	80 ,,
Waterstones	120 ,,
Coal-measures [?]	353 ,,
	615 ,,

There have been also borings, of which details are not forthcoming, at the undermentioned localities :—

Near Kingshill Spinney, one mile and a half south-west of Market Bosworth, ending at a depth of about 672 feet, probably in Waterstones.

At Bosworth Wharf, one mile west of Market Bosworth.

At Cowpasture, three-quarters of a mile north-east of Market Bosworth, said to have entered Cambrian or Lower Silurian rocks at 400 feet.

Near Gabriel Pool, ¾ of a mile N.N.W. of Newbold Vernon, to a depth of 266 feet.

Newbold Heath, half a mile W.S.W. of the Landridge boring mentioned above, in which Coal-measures were said to have been proved at a depth of 400 feet.

There can be little doubt therefore that, as pointed out by Mr. Harrison,[4] the Trias rests directly upon rocks older than the Coal-measures over a large part of the area. Whether or no the Coal-measures were ever deposited continuously over the area remains an open question. It is certain that the Silurian rocks had suffered

[1] The lower part of this subdivision was attributed to the Permian by Sir Andrew Ramsay, who gave the following details (Report of the Coal Commission, 1871, vol. ii. p. 134) :—

Permian	Loose sandstone	64 feet.
	Hard sandstone	17 ,,
	Light and dark sandstone	43 ,,
	Pebbles, hard conglomerate	2 ,,
	Pink and purple marls	15 ,,
Coal-measures [now known to be Silurian or of earlier age]		141 ,,

[2] Report of the British Association for 1875 (Report of the Committee on the Circulation of Underground Waters), p. 137.

[3] Report of the British Association for 1878 (Report on the Circulation of Underground Waters), pp. 6, 7.

[4] Midland Naturalist, vol. viii. (1885).

enormous denudation in pre-Carboniferous times, so great indeed as to remove the whole of the series, consisting in the aggregate of several thousand feet of rock, from parts of Leicestershire. And it is probable that in the period of submergence that succeeded this continental epoch most of even the higher parts of the old land-surface in this neighbourhood were overspread by the latest Coal-measure sediments. But, however this may have been, the Carboniferous rocks were swept bodily off large areas in the Midland Counties in the long period of denudation which preceded the Trias. There are therefore two questions to be taken into consideration, in speculating on the possible presence of Coal-measures under the Trias at any point in the Midland Counties: firstly, whether the Coal-measures ever existed at that point; secondly, whether, having existed, they were subsequently removed by pre-Triassic denudation. It is scarcely possible to attach too much importance to the study of the great unconformity at the base of the Trias. In the present instance it seems certain, that though the Coal-measures may have been deposited in a continuous sheet between the Leicester and Warwick Coal-fields, they were certainly swept clean off, as far north as Market Bosworth and perhaps further, before the Waterstones and Marls were deposited.

Appendix I.

III.—The Igneous Rocks, etc., of the Neighbourhood of the Warwickshire Coal-field.

By Frank Rutley, F.G.S., etc.

THESE rocks may be classed into five or six more or less distinct groups.

I. Syenitic Rocks (Croft Series).
II. Andesite and Andesitic Tuffs (Caldecote Series).
III. Hartshill Quartzite with Breccia at its base.
IV. Diorites.
V. Andesites or Diorites containing Augite.
VI. Basalts or Diorites containing Olivine.

The three last groups appear to graduate into one another, and seem to correspond with similar rocks described by Mr. Allport.[1] Many of the specimens examined are in a more or less advanced stage of decomposition, calcite, serpentine, pyrites, etc., being very commonly present.

The best example of diorite in the series is that from the Oldbury Reservoir. These rocks are of special petrographical interest since so few diorites have been found in England. The mineral constitution of some of these rocks is such that they are also interesting from the transitional characters which they present between diorite, basalt and andesite or diabase. The pseudomorphs after olivine met with in the sections of rock here described might rather, as a rule, be called metasomata, since well-developed forms of the original crystals

[1] On the Diorites of the Warwickshire Coal-field, Q.J.G.S. vol. xxxv. p. 637.

are often wanting, and it is seldom that any unaltered olivine is present. The replacing substance is frequently calcite. Accepting, therefore, the conclusions of Allport, who was fortunate in finding good crystals of unaltered olivine in some of the dioritic rocks of this district, and coupling them with such evidence of the former presence of this mineral as the sections, here described, afford, there seems little doubt that we have, in some cases, rocks which may often, with equal justice, be termed either olivine-bearing diorites or hornblendic basalts. On the other hand, the association of augite with hornblende in some of these rocks, also described by Allport, gives rise to a like ambiguity, since in these we may have either hornblendic diabases or andesites, or augitic diorites.

The term augite-diorite has already been employed by Zirkel,[1] and its use advocated afresh by Grenville A. J. Cole.[2] The sanction of such a term, although its meaning is evident and not opposed to the observed mineral constitution of these rocks, may however, lead to some present confusion in petrological nomenclature, since the currently accepted definition of a diorite indicates that the constituent minerals are essentially triclinic felspar (labradorite or oligoclase) and hornblende. The important point in naming rocks of this mixed character is to indicate their relationship on either hand to sharply and of course arbitrarily defined rock types when their position is so evenly balanced between two types that the rock cannot be referred to the one type more than to the other, and, to indicate this, I would suggest that the names of the two nearest types should be combined, a preponderating affinity towards the one type or the other being denoted by underlining the name of the dominant type. Thus in the case of those olivine-bearing rocks which approximate on the one hand to diorites and on the other to basalt, we should have

Diorite. Diorite-Basalt. Diorite Basalt. Diorite-Basalt. Basalt.

A nomenclature based upon mineralogical terms only is never likely to be adopted, since it is far too cumbrous. Rock-names taken singly fail to indicate transitions in mineral constitution, while a mixture of mineralogical and petrological names at once impairs the needfully, but unnaturally sharp definition of a type. It therefore seems better to employ already well-known words and preserve, so far as possible, the landmarks of classification, than to destroy the meaning of a term by a mineralogical prefix or affix which in conveying a small truth may breed a great misconception. If, for instance, augite or olivine were assumed to be anything more than occasional and subordinate constituents of a diorite, the commonly accepted definition of that rock would become worthless, since the term diorite would then embrace a number of rocks of far greater importance and wider distribution, which have hitherto been distinguished by other names.

That a relationship exists between such rocks, and that they graduate one into another, is too well known to need any comment,

[1] "Lehrbuch der Petrographie," vol. ii. p. 7, Bonn, 1866.

[2] "The Igneous Rocks of Stanner," GEOL. MAG. Decade III. Vol. III. p. 225 (May, 1886).

but, to have classification, more or less clear definitions must be employed; without these the whole series of basalts, andesites and diorites may as well be called Greenstones.

I. Syenitic Rocks.

Croft.[1]

Pinkish-grey crystalline rock, resembling a fine-grained granite and apparently composed of pinkish or flesh-coloured felspar, a very little dark mica, quartz, and some dark specks of hornblende and magnetite. Under the microscope the rock is seen to have a holocrystalline granitic structure, and to consist chiefly of orthoclase and triclinic felspars, quartz, hornblende and magnetite, with possibly a little magnesian mica. The amount of triclinic felspar present renders it necessary to distinguish this rock from an ordinary quartz-syenite. It is an orthoclase-plagioclase syenite, in other words it occupies a position between quartz-syenite and quartz-diorite.

Croft.

A pinkish-brown crystalline rock with numerous white, porphyritic crystals seldom over one-eighth of an inch in diameter, and small dark greenish-black and black specks. The specimen has a weathered appearance.

Under the microscope it is seen to consist of orthoclase, a triclinic felspar, which from some of the extinction angles seems to be albite, hornblende in small irregularly developed crystals which are sometimes represented by serpentinous pseudomorphs and crystals and irregular grains of magnetite. Quartz occurs plentifully. The rock is essentially a quartz-syenite. It is a more coarsely crystalline rock than the preceding.

Croft.

A purplish or reddish-grey, fine-grained crystalline rock, with dark brown spots ranging up to an eighth of an inch in diameter.

Under the microscope the chief constituents are seen to be felspars, all of which are greatly altered, so that their optical characters afford no clue to the species, quartz, serpentine, apparently pseudomorphous after hornblende, and ilmenite partly converted into leucoxene.

The rock seems to be a decomposed, fine-grained, quartz-syenite.

II. Andesite and Andesitic Tuffs, Caldecote Series.

Old tunnel, near Caldecote Hill.[2] Caldecote Series.

A finely-laminated greenish-brown rock, resembling a fine-grained sandy-mudstone or slate. The specimen is bounded by parallel joint-planes. Under the microscope, with a power of about 75 linear, a considerable proportion of the rock appears between crossed Nicols to consist of isotropic matter finely stippled with very minute doubly refracting granules and traversed by irregular wavy films of a serpentinous or sericitic substance, which commonly runs in sinuous

[1] See also "On the Pre-Carboniferous Rocks of Charnwood Forest," by the Rev. T. G. Bonney and Rev. E. Hill, Q.J.G.S. vol. xxxiv. pp. 119–239, 1878.

[2] See also T. H. Waller, Geol. Mag. 1886, p. 323.

streaks approximately parallel to the lamination of the rock. The entire section is profusely spotted with small crystals and fragments of crystals of felspar and augite, the latter mineral being usually represented by pseudomorphs of limonite. Some of the sections of augite crystals undergo maximum extinction at an angle of about 39° from the vertical axis, while other sections transverse to the vertical axis show approximately right angles formed by the adjacent faces of the oblique rhombic prism. The felspars are generally labradorite. Taking into consideration all the characters presented by this rock, it seems highly probable that it is an altered andesitic tuff.

"Blue Hole," east of Caldecote Windmill.[1] Caldecote Series. (The Quartz-Porphyry.)

Rock composed of pink and greyish-white crystals of triclinic felspar with grains of quartz, in a dark bluish- or brownish-grey matrix, the latter constituting the smaller proportion of the rock.

Under the microscope the general appearance is that of a tuff, composed of crystals or fragments of crystals of triclinic felspar and quartz more or less corroded, together with fragments of eruptive rock of an andesitic type, containing serpentinous pseudomorphs after pyroxene. The porphyritic felspar crystals, all of which have their angles rounded, are often corroded superficially and their angles of extinction indicate, as a rule, that they are labradorite. The quartz crystals are also rounded, and frequently show inlets of corrosion, which are much more strongly marked than in the felspars. The material in which these crystals and fragments are embedded is felsitic in character, and as it seems to be continuous with the felsitic matter which fills the corrosion-creeks in the quartz-crystals, it appears probable that it may be a product of devitrification, and that the rock is a tuff resulting from fragments taken up in a magma which, on solidification, assumed a vitreous condition. The general appearance of this rock under the microscope is rather like that of certain porphyritic pitchstones occurring in Saxony, except that in the latter the porphyritic crystals or fragments are usually less numerous and the ground-mass retains its glassy character. It seems probable that this rock from Caldecote is part of a lava-flow or dyke which has taken up fragments of other rocks in such quantity that it simulates an ordinary volcanic tuff.

"Blue Hole," east of Caldecote Windmill. Caldecote Series. (Junction of Quartz-Porphyry and Andesite).

Compact bluish-grey to brownish-grey rock with splintery fracture. The small specimen contains in one part greyish-white to pinkish-white specks of felspar, the largest being about $\frac{1}{16}$ inch in diameter. Minute grains of quartz are also visible with a lens.

Under the microscope, between crossed Nicols, the section seems to consist chiefly of a crypto-crystalline to micro-crystalline admixture of felspar and quartz, with some irregularly-shaped and usually rounded grains which, by ordinary transmitted light, appear of a brownish-green colour, and which are probably altered fragments

[1] See also T. H. Waller, Geol. Mag. 1886, p. 323.

of crystals of pyroxene or amphibole. A similar green or brownish-green substance (chlorite?), accompanied by minute specks of opaque-white matter (kaolin), constitutes irregular stringy markings and sinuous bands, which traverse the section, in some cases simulating fluxion structure, the material between such bands sometimes differing in texture from that on either side. This seems to be due to the presence of fragments of rock, whose margins are ill-defined, except through the contact of the chloritic films and strings. Small angular and rounded fragments of felspar crystals are plentifully distributed throughout the section, and here and there opaque grains of ilmenite, partly converted into leucoxene, are visible.

The porphyritic crystals and fragments of crystals of felspar mostly give extinction angles approximating to 40°, and may therefore be regarded as anorthite. In a few cases, however, labradorite occurs.

Judging from the section, it seems probable that this rock is a tuff composed of lapilli of some rocks allied to andesite or porphyrite in which the ground-mass was once vitreous or partly so.

"Blue Hole," east of Caldecote Windmill.[1] Caldecote Series. (Andesite.)

Compact purplish-grey rock, in which a few minute felspar crystals may be detected with a lens.

Under the microscope the section is seen to consist of crystals of triclinic felspars and magnetite in a felsitic or aphanitic ground-mass, in which numerous very minute crystals occur, which are apparently hornblende, since in some cases they give an extinction angle of 19°.

If these small crystals be hornblende, the rock is probably a hornblende andesite. It is somewhat decomposed, the specimen effervescing slightly when treated with acid. Isotropic matter seems to be present and it is quite possible that the rock may have originally possessed a more or less glassy ground-mass, some of the unaltered vitreous matter being apparently still present.

III. Hartshill Quartzite with Breccia at its base.

Base of Hartshill quartzite, half a mile S.E. of Hartshill.

A coarse breccia consisting of angular fragments embedded in a bluish-grey to purplish matrix. On a cut surface of the specimen some of the fragments are of a dark slate-colour or purple, while others are of a rather pale greenish-grey. The fragments do not seem to exceed half an inch in diameter, and most of them are of much smaller dimensions.

Under the microscope the fragments are seen to be of a mixed character. A few consist of eruptive rock, one or two showing distinct felspar crystals (labradorite), while one fragment contains small vesicles filled with a pale green substance (chlorite?). Quartz grains constitute a large proportion of the rock, and most of the other fragments and grains consist either of greatly decomposed

[1] See also T. H. Waller, Geol. Mag. 1886, p. 324. The Dark Basic Rock.

felspar, converted into felsitic matter, or fragments of quartzite, and fragments of slate, together with grains of magnetite. The fragments of volcanic rock appear to be of an andesitic type. The slate fragments are the largest and the most numerous.

Hartshill Quartzite.[1]

A very fine-grained pinkish-grey rock resembling quartzite.

Under the microscope the rock appears to consist chiefly of irregular crystalline grains of quartz containing numerous minute fluid lacunæ, with a few grains of felspar, which from the extinctions are seen in some cases to be microcline, in others anorthite. Grains of a clear, colourless, isotropic mineral are also present, which are probably garnet. Here and there but quite rarely a little microcrystalline siliceous matter may be seen lying in thin films or occupying small spaces between the quartz grains. The rock is essentially a quartzite.

IV., V. and VI. Diorites; Andesites, or Diorites containing Augite; Basalt, or Diorites containing Olivine.[2]

The specimens are taken in geographical order.

Marston Jabet. Intrusive in Lower Silurian Shales.

A rather coarsely crystalline greenish-grey rock, consisting of greyish crystals of felspar, a dark green mineral, calcite and specks of pyrites.

Under the microscope the section shows, triclinic felspar crystals (labradorite), serpentinous matter pseudomorphous after hornblende, the crystals being frequently about $\frac{1}{16}$ inch in diameter and giving in sections transverse to the vertical axis the usual prismatic angle for hornblende. These pseudomorphs are mostly flecked with an opaque yellowish-white substance probably leucoxene. Well-defined pseudomorphs of leucoxene after ilmenite are also present, the alteration being so complete that scarcely a trace of the original mineral remains. Spots of pyrites and large patches of calcite occur, and serpentine, frequently fibrous and in spherical groups of divergent fibres, often fills the spaces between the larger crystals. Apatite is also plentiful in well-formed crystals. The rock is a diorite, as pointed out by Mr. Allport in the paper already cited, where descriptions of the microscopic characters of this rock in its fresh condition and in various stages of alteration are very clearly given.

Griff Farm (South of). Intrusive in Lower Silurian Shales.

A bluish- to brownish-grey crystalline rock containing specks of pyrites.

Under the microscope this is seen to be composed of crystals of labradorite and hornblende with a considerable amount of serpentine or a pale greenish substance which appears to be serpentine, and which occasionally occurs in small spherical or fan-like fibrous

[1] See also T. H. Waller, Geol. Mag. 1866, p. 235. The Quartzite.

[2] See also J. J. H. Teall, Hornblende-Bearing Rocks, Geol. Mag. 1886, p. 351.

aggregates. There is also some calcite present, the rock effervescing briskly when touched with acid. It is a diorite.

Chilvers Coton Railway-Cutting. A sheet three inches thick in Lower Silurian Shales.

A greenish-grey or greyish-green rock of very fine texture, profusely speckled with dark-green crystals and containing much pyrites, crystallized in cubes.

Under the microscope this rock appears to consist of pale green serpentinous matter with interlacing sheaf-like aggregates of small slender acicular crystals, having frequently rather ragged boundaries. These crystals often undergo extinction at an angle of 19° from their longest diameter, and it may be assumed from this and from their pleochroism that they are hornblende. There appears to be very little felspathic matter in this rock. There are, however, a few imperfectly formed crystals of labradorite present. The serpentine may possibly be pseudomorphous after olivine, but the sections are very irregular in form, and there is no positive evidence upon this point. A few grains of augite are visible in this section, as well as irregularly-shaped patches of pyrites.

Chilvers Coton Railway-Cutting. Intrusive in Lower Silurian Shales.

A medium-grained crystalline rock of a pinkish-grey, closely speckled with dull green crystals and containing minute specks of pyrites.

Under the microscope it is seen to consist of triclinic felspar, hornblende, rather sparsely distributed grains of magnetite and pyrites, a very few minute crystals of apatite and some isotropic or nearly isotropic matter, which may represent an interstitial glass. The felspar appears as a rule to be labradorite. The rock is essentially a diorite.

Chilvers Coton Railway-Cutting. Intrusive in Lower Silurian Shales. Three feet from top of dyke.

A greenish-grey crystalline rock of fine texture, containing numerous minute specks of pyrites.

The constituents of this rock appear under the microscope to be triclinic felspar (labradorite), serpentine, apatite pyrites, and a little unaltered augite. The serpentine, which is very plentiful in the section, may be an alteration product after augite or after some other mineral, but upon this point the section affords no trustworthy evidence. The rock is probably some kind of andesite.

Midland Quarry, Nuneaton Station. Intrusive in Hartshill Quartzite.

A very fine-grained purplish-grey rock showing under a pocket-lens a small quantity of a light-green mineral resembling epidote and minute octahedra of magnetite. The specimen attracts the magnetic needle.

Under the microscope the constituents are seen to be triclinic felspar, augite, olivine, magnetite, and serpentine, the latter sub-

stance being probably pseudomorphous after olivine. A few fan-like or divergent groups of capillary crystals occur here and there in the section. They undergo extinction approximately parallel to the longest axes of the minute rods, and are probably epidote. The magnetite occurs in irregularly-shaped grains and in well-developed octahedra. A little hornblende may be present, but the evidence for this is not satisfactory. The rock is a diabase.

Stockingford Cutting, Midland Railway (E. of bridge). Intrusive in Lower Silurian Shales.

A very fine-grained, greenish-grey crystalline rock, containing small spots and very numerous minute specks of pyrites. The rock effervesces freely when touched with acid.

Under the microscope it is seen to consist of triclinic felspar (labradorite), serpentine often in pseudomorphs after olivine, hornblende, pyrites, calcite, and specks of a yellowish white substance, either kaolin or leucoxene, but probably the former. It is difficult to say whether this rock is to be regarded as a basalt or a diorite. The occurrence of olivine in dioritic rocks from this neighbourhood has already been noticed by Mr. S. Allport.[1]

Midland Railway, Stockingford Cutting, Nuneaton. Upper surface of dyke intrusive in Lower Silurian Shales.

A very fine-grained greenish-grey or drab-coloured crystalline rock, showing numerous minute specks of pyrites.

Under the microscope the constituents appear to be chiefly triclinic felspar, serpentine pseudomorphous after hornblende, a very little unaltered hornblende and a considerable quantity of pyrites, some of which occurs in triangular sections which give angles of approximately 110° (the angle formed by the edges of an octahedron). It therefore seems probable that the pyrites in this case is pseudomorphous after magnetite, and this appears the more likely since no magnetite is visible in the section, although the rock is one in which this mineral is generally present. So far as I am aware, pseudomorphs of pyrites after magnetite are of very unusual occurrence, but instances are quoted by Delesse.[2] The rock is a diorite.

Oldbury Reservoir. Very thick sheet intrusive in Lower Silurian Shales.

A greenish-grey crystalline rock, spotted with numerous dark-green or blackish crystals of hornblende. It also shows many specks of pyrites and the joint planes are coated with calc-spar.

Under the microscope the rock is seen to be composed of triclinic felspar, crystals of hornblende, larger than those seen in the rocks already described, and exhibiting the interrupted crystallization, sometimes termed ophitic, a considerable quantity of kaolin, specks of pyrites and also a little calcite. The rock is a diorite.

[1] Quart. Journ. Geol. Soc. vol. xxxv. p. 639.

[2] Récherches sur les Pseudomorphoses, Tableau II. p. 52, Annales des Mines, t. xvi. 1859.

Dosthill (intrusive in Lower Silurian Shales).

A fine-grained greenish- to greyish-brown crystalline rock.

Under the microscope it is seen to consist of more or less imperfectly developed lath-shaped crystals of triclinic felspar, which, from the extinction angles of some of them, appear to be labradorite, octahedra and irregularly-shaped grains of magnetite, apatite and pseudomorphs of serpentine, apparently after hornblende, since the angles of some of these pseudomorphs correspond with the angle of the oblique rhombic prism in hornblende.

The rock may be regarded as an altered diorite.

Appendix II.

IV.—On the New Species *Olenus Nuneatonensis* and *Obolella granulata*, from the Lower Silurian ('Cambrian,' Lapworth), near Nuneaton.

By George Sharman, Esq.

Olenus Nuneatonensis, S., sp. nov.

Locality.—West end of the Midland Railway cutting, between Nuneaton and Stockingford.

Several fragmentary specimens of this Trilobite, differing in size, yet exhibiting similar characters, have been collected from this locality. The most perfect, although one of the smallest, is best fitted for description.

The length of this specimen is three-eighths of an inch, and the head, or cephalic-shield, is rather more than one-third of the entire length. The glabella is very convex, slightly narrowing in front, but inflated and bending over the frontal margin. The neck-furrow is distinct, the basal groove runs across the glabella, and there appear to be two short indistinct furrows on each side. There are eleven to thirteen body-rings, the pleuræ of the 5th, 6th, and 7th bearing short spines, and the 8th possessing a produced spine half as long as the specimen itself, and projecting beyond the end of the tail. The four terminal segments of the body also have spines, lessening in length towards the tail. The tail is short, the axis showing it to be composed of three, or perhaps more segments; it narrows posteriorly, and is subtruncate, being indented as in *O. micrurus*.

This species is distinguished from *O. micrurus* by the more lengthened spines from the posterior angles of the cheeks, and the possession of those attached to the pleuræ of the lower segments of the body, the nearer approach and bending over of the glabella towards the anterior margin, the continuance of the basal groove across the glabella, and in the anterior portion of the body being more parallel-sided. The character of the tail appears in all respects to agree with that of *O. micrurus*.

It is distinguished from *O. bisulcatus*, Phil., by the absence of the mesial spine on the cephalic-shield.

The marked difference in the size of these Trilobites (as before mentioned) would undoubtedly suggest the probable presence of two

species, yet after a careful examination of the larger specimens, which are unfortunately only fragments, the characters appear to be the same as those of the smaller ones just described, and therefore, until better specimens can be found, they are regarded as the same species.

Obolella granulata, S., sp. nov.

Locality.—Lane on the south side of Purley Park, near Atherstone.

Only two specimens have been collected by the Survey, and although somewhat imperfect, yet they exhibit characters separating them from previously described species.

On first viewing the specimens, the form and general appearance of *Siphonotreta* is strongly suggested, but the structure and ornamentation is found on closer examination to differ considerably from it; radiating ribs apparently underneath the general surface of the shell are clearly seen extending from the beak towards the margin, and these commencing and terminating irregularly, none however quite reaching from the beak to the margin of the shell.

The surface of the whole shell is minutely granulated, giving an appearance of very fine concentric wavy lines. The umbonal region not being quite perfect prevents any definite determination of the genus, but provisionally it is placed with *Obolella*.

V.—On the Ffynnon Beuno and Cae Gwyn Caves.

By Henry Hicks, M.D., F.R.S., F.G.S.

THE best reply that I can make to Prof. Hughes' remarks, in the Geological Magazine for November, on the Ffynnon Beuno Caves, is to publish the substance of the report presented to the British Association, especially as an opportunity will be given to those interested in the inquiry to examine the section during the further explorations to be carried on, probably in the month of June next year. Some of his statements—especially as regards the position of the fence, which is entirely at the opposite end of the cavern to that at which the flint flake was found, also as to the position of the flake, and the nature of the deposits overlying it—are so entirely misleading, that I can only account for such statements being made by the fact that Prof. Hughes did not visit the section, though strongly urged by me to do so, until it had been almost entirely covered over, and work for the time suspended, and by his hasty survey of the surrounding conditions.[1] That such experienced

[1] It is surprising that Prof. Hughes did not recognize that the accumulation against the upper side of the old fence, "until there is now a drop of eight feet to the level of the ground on the lower side of the fence," mentioned by him as of such great importance, is merely material conveyed there during the explorations. Before work was commenced, the space between the old fence and the entrance was almost bare rock, and there was nothing resting against the fence. No wonder then that he should have come to the conclusion that this was remanié drift, and that he thought he recognized on some of the stones "traces of agricultural implements as well as true Glacial striæ." The remarkable thing is that he should not have recognized the difference between this very recently mixed material near the old entrance and the stratified deposits in the shaft at the other end of the cavern. The term "Clwydian," if it is at all advisable to give local names to drift, is a most unsuitable name for the *undisturbed* glacial deposits on the higher levels, and should be confined to those at and about St. Asaph, which are at a low level near the centre of the Vale of Clwyd, and

geologists as Prof. Boyd Dawkins, Mr. Morton, Mr. De Rance, Mr. Strahan, Mr. Shone, and Dr. Stolterfoth, should, after careful examination, have been perfectly satisfied that the Glacial deposits overlying the flake and Mammalian remains were in an entirely undisturbed condition, and that they agreed with the views of the members of the Committee (Mr. Luxmoore, Mr. P. P. Pennant, Mr. E. Morgan, and myself), who were almost daily present at the explorations, is, I think, ample proof that Prof. Hughes' deductions are entirely at variance with the facts.

Report of the Committee, consisting of Professor T. McK. Hughes, M.A., F.G.S., H. Hicks, M.D., F.R.S., H. Woodward, LL.D., F.R.S., E. B. Luxmoore, M.A., P. P. Pennant, M.A., and Edwin Morgan, appointed for the purpose of exploring the Caves of North Wales.—Drawn up by Dr. H. Hicks, Secretary.

The explorations conducted by the Committee have been confined to the caverns of Ffynnon Beuno and Cae Gwyn, in the Vale of Clwyd. These caverns had been explored in preceding years by Dr. H. Hicks and Mr. E. B. Luxmoore, some of the results being given in a paper communicated to the Geological Section of the Association in 1885, but more fully in a paper in the Quart. Journ. Geol. Soc. February, 1886.

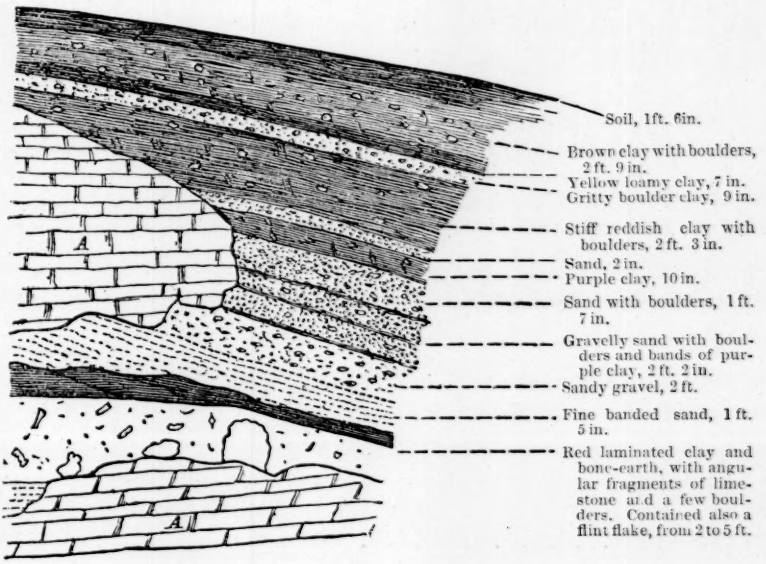
between the important rivers Elwy and Clwyd. This is in the main part remanié, and as such the term "Clwydian" might be applied to it. The undisturbed glacial deposits, stratified marine sands, and the overlying clay, containing large boulders of local rocks and northern erratics, found at Cae Gwyn and at so many other points in the neighbourhood at a high level far away from, and beyond the influence of any important river, ought not, on any account, to be termed "Clwydian." The true glacial deposits which overlaid the Mammalian remains and flint flake at the entrance to Cae Gwyn Cave belong to a much earlier phase than the Clwydian drift about St. Asaph and at other low levels in the valley, bordering the great rivers. The Cefn and Plas Heaton Caves, mentioned by Prof. Hughes, are also at a very much lower level than the Ffynnon Beuno Caves, and are so near to the rivers that I do not think the evidence furnished by them can be quoted as of much value either way, though it is well known that many have contended that the evidence in the Cefn Cave was distinctly in favour of its having been occupied by the animals before the great submergence in the Glacial period. The evidence cited by Mr. Strahan, in his recent excellent Memoir, as having been obtained in sinking shafts at the Talargoch mines, conclusively proves that Mammalian remains occur there in the very lowest glacial deposits. It is the great height at which the Ffynnon Beuno Caves occur, the impossibility of their having been disturbed by fresh water, the evidence of their having been occupied as dens before the great submergence, of the stalagmite floor having been broken up by marine action, of the bones having been cased in marine sand, and of the caverns having afterwards been completely buried under marine sand and an overlying undoubted boulder clay, containing many large ice-scratched boulders, that make the evidence found in them and in their immediate neighbourhood of such great value. The facts in my opinion are conclusive, and they cannot be altered by any amount of special pleading. Prof. Hughes' argument about the absence of flint and other foreign rocks in what he calls the oldest deposit, is founded on negative evidence derived from a limited examination. Mr. Strahan, the latest authority on the drift of this area, says (Geol. Survey Mem. 1885), "The passage from the one Boulder clay into the other is gradual, nor can it be said that one under or overlies the other. They were no doubt formed contemporaneously, differing only in the source of supply of material." Sir C. Lyell in speaking of the Moel Tryfaen beds says ("Student's Elements," 1871), "In the lowest beds of the drift were large heavy boulders of far-transported rocks, glacially polished and scratched on more than one side." Prof. Hughes' palæontological argument is found on examination to be almost equally inapplicable, as a very large proportion of the animals occur in the Norfolk forest-bed, which is acknowledged by all to be of pre-Glacial age. The fact that some others have not been found in the caverns probably indicates that they did not migrate into this area.

Among the remains discovered in these two caverns up to the commencement of the work this year there were over eighty jaws belonging to various animals, and more than 1300 loose teeth, including about 400 Rhinoceros, 15 Mammoth, 180 Hyæna, and 500 Horse teeth. Other bones and fragments of bones occurred also in very great abundance. Several flint implements, including flakes, scrapers, and lance-heads, were found in association with the bones. The most important evidence, however, obtained in previous researches was that bearing on the physical changes to which the area must have been subjected since the caverns were occupied by the animals. During the excavations it became clear that the bones had been greatly disturbed by water action, that the stalagmite floor, in parts more than a foot in thickness, and massive stalactites had also been broken and thrown about in all positions, and that these had been covered afterwards by clays and sand containing foreign pebbles. This seemed to prove that the caverns, now 400 feet above Ordnance datum, must have been submerged subsequently to their occupation by the animals and by Man. One of the principal objects, therefore, which the Committee had in view this year was to critically examine those portions of the caverns not previously explored, so as to endeavour to arrive at the true cause of the peculiar conditions observed. Work was commenced at the end of May, and carried on during the whole of June and parts of July and August.

Cae Gwyn Cave.

When the explorations were suspended last year, it was supposed that we had just reached a chamber of considerable size, but after a few days' work this year it was found that what appeared to be a chamber was a gradual widening of the cavern towards a covered entrance. The position of this entrance greatly surprised us, as hitherto we had believed that we were gradually getting further into the limestone hill. The rise in the field at this point, however, proved to be composed of a considerable thickness of glacial deposits heaped up against a limestone cliff. As the materials covering the bone-earth within and at the entrance were chiefly sands and gravels, it was found necessary to suspend operations in that direction and to ask the landlord (E. Morgan, Esq.) for permission to open a shaft directly over this entrance from the field above. As this necessitated the removal of a considerable surface of land, and caused some damage to the field, the Committee feel that their special thanks are due to Mr. Morgan for his kindness in so readily acceding to their application. This shaft, as at first opened, was about nine feet across at the surface and over five feet at the bottom. It was subsequently widened at the bottom in consequence of some falls and the lower part, excepting at one point, had to be carefully faced with timber. The upper part is now much widened and sloped. The shaft was about twenty feet in depth, and the deposits as shown in Fig. 1 were made out in it. These were carefully measured by Mr. C. E. de Rance, F.G.S., Mr. Luxmoore, and the writer during the prosecution of the work. Below the soil, for about eight feet, a

tolerably stiff boulder clay, containing many ice-scratched boulders and narrow bands and pockets of sand, was found. Below this there were about seven feet of gravel and sand, with here and there bands of red clay, having also many ice-scratched boulders. The next deposit met with was a laminated brown clay, and under this was found the bone-earth, a brown, sandy clay with small pebbles and with angular fragments of limestone, stalagmite, and stalactites.


A
A
Soil, 1ft. 6in.
Brown clay with boulders, 2 ft. 9 in.
Yellow loamy clay, 7 in.
Gritty boulder clay, 9 in.
Stiff reddish clay with boulders, 2 ft. 3 in.
Sand, 2 in.
Purple clay, 10 in.
Sand with boulders, 1 ft. 7 in.
Gravelly sand with boulders and bands of purple clay, 2 ft. 2 in.
Sandy gravel, 2 ft.
Fine banded sand, 1 ft. 5 in.
Red laminated clay and bone-earth, with angular fragments of limestone and a few boulders. Contained also a flint flake, from 2 to 5 ft.

A. Carboniferous Limestone. ◊ Position of the flint flake.

Fig. 1. Section at New Entrance to Cae Gwyn Cave.

On June 28, in the presence of Mr. G. H. Morton, F.G.S., of Liverpool, and the writer, a small but well-worked flint flake was dug up from the bone-earth on the south side of the entrance. Its position was about eighteen inches below the lowest bed of sand. Several teeth of Hyæna and Reindeer, as well as fragments of bone, were also found at the same place, and at other points in the shaft teeth of Rhinoceros and a fragment of a Mammoth's tooth. One Rhinoceros tooth was found at the extreme point examined, about six feet beyond and directly in front of the entrance. It seems clear that the contents of the cavern must have been washed out by marine action during the great submergence in mid-Glacial time, and that they were afterwards covered by marine sands and by an upper-boulder clay, identical in character with that found at many points in the Vale of Clwyd and in other places on the North Wales coast. Figs. 2 and 3 explain the order of the deposits as found within the cavern.

Fig. 3 was taken at a distance of about sixteen feet from the entrance at the shaft, and Fig. 2 just within that entrance. The order in that portion of the cavern examined this year accorded in the main with that found during the previous researches, but within the entrance there was a greater thickness of sand, less of the laminated clay, and more bone-earth than in the other parts of the cavern. The bone-earth seems to diminish in thickness rather rapidly outwards under the glacial deposits, but it was found as far out as the excavations have been made. Here the bone-earth rests directly on the limestone floor, with no local gravel between, as in the cavern.

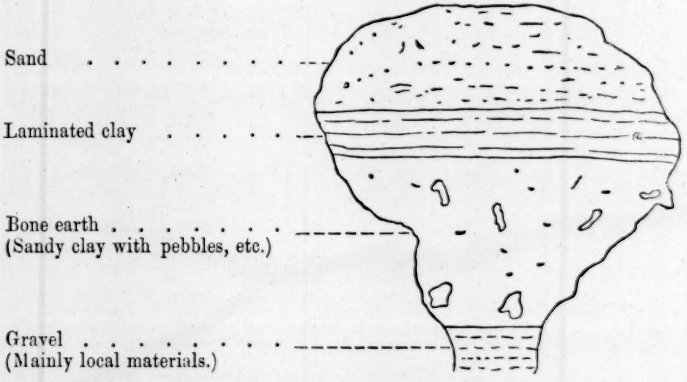


Fig. 2. Section in Cae Gwyn Cave, near the New Entrance.

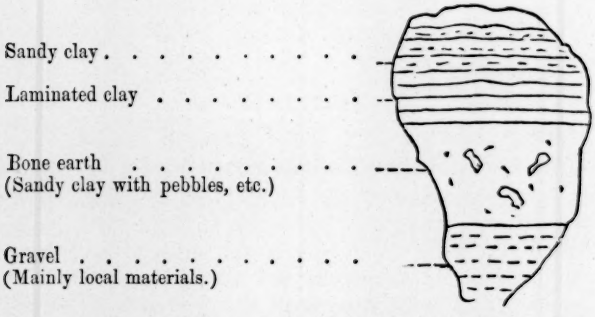


Fig. 3. Section in Cae Gwyn Cave, about 16 feet from the New Entrance.

It would be interesting to know how far the cave earth extends under the glacial deposits, but this could only be ascertained by making a deep cutting through the terrace of glacial deposits, which extends for a considerable distance in a westerly direction. The glacial deposits here are undoubtedly in an entirely undisturbed condition, and are full of smooth and well-scratched boulders, many of them being of considerable size. Among the boulders found are granites, gneiss, quartzites, flint, felsites, diorites, volcanic ash,

Silurian rocks, and limestone. Silurian rocks are most abundant. It is clear that we have here rocks from northern sources, along with those from the Welsh hills, and the manner in which the limestone at the entrance to the cavern in the shaft is smoothed from the north would indicate that to be the main direction of the flow. The marine sands and gravels which rest immediately on the bone-earth are probably of the age of the Moel Tryfaen and other high-level sands, and the overlying clay with large boulders and intercalated sands may be considered of the age of the so-called upper-boulder clay of the area. The latter must evidently have been deposited by coast-ice. Whether the caverns were occupied in pre- or only in inter-glacial times it is difficult to decide, but it is certain that they were frequented by Pleistocene animals and by Man before the characteristic glacial deposits of this area were accumulated. The local gravel found in the caverns, underlying the bone-earth, must have been washed in by streams at an earlier period, probably before the excavation of the rocky floor of the valley to its present depth. From the glacial period up to the present time excavation has taken place only in the glacial deposits, which must have filled the valley up to a level considerably above the entrances to the caverns. The characteristic red boulder clay with erratic blocks from northern sources is found in this area to a height of about 500 feet, and sands and gravels in the mountains to the S.E. to an elevation of about 1400 feet. The natural conclusion therefore is that the caverns were occupied by an early Pleistocene fauna and by Man anterior to the great submergence indicated by the high-level marine sands, and therefore also before the deposition of the so-called great upper-boulder clay of this area. As there is no evidence against such a view, it may even be legitimately assumed that the ossiferous remains and the flint implements are of an earlier date than any glacial deposits found in this area.

Ffynnon Beuno Cave.

This cavern, which yielded the greatest number of bones in the previous researches, has now been cleared out in all those parts where the deposits appeared to have been undisturbed by Man. A considerable addition to the number of bones and teeth has been made this year, but no new forms have to be added to those already mentioned.

The animal remains found in the caves, as defined by Mr. W. Davies, F.G.S., of the British Museum, comprise teeth and bones of eleven genera and sixteen species, as shown by the annexed list:—

Lion (*Felis leo*, var. *spelæa*).
Wild Cat (*F. catus ferus*).
Spotted Hyæna (*H. crocuta*, var. *spelæa*).
Wolf (*Canis lupus*).
Fox (*C. vulpes*).
Bear (*Ursus*, sp.).
Badger (*Meles taxus*).
Wild Boar (*Sus scrofa*).
Bovine (*Bos ? Bison ?*).
Great Irish Deer (*Cervus giganteus*).
Red Deer (*Cervus elaphus*).
Roebuck (*C. capreolus*).
Reindeer (*C. tarandus*).
Horse (*Equus caballus*).
Woolly Rhinoceros (*R. tichorhinus*).
Mammoth (*Elephas primigenius*).

REPORTS AND PROCEEDINGS.

I.—November 3, 1886.—Prof. J. W. Judd, F.R.S., President, in the Chair.

The President noticed the presentation, on the part of Dr. Hector, of a preliminary report of the late eruptions in New Zealand, and stated that Dr. Hector hoped shortly to communicate a paper to the Society on the subject; papers had also been sent or promised on the same subject by other New Zealand geologists, and it was hoped that before long the Society would be in possession of very full accounts of these remarkable volcanic outbursts.

The following communications were read:—

1. "On the Skull and Dentition of a Triassic Saurian, *Galesaurus planiceps*, Ow." By Sir Richard Owen, K.C.B., F.R.S., F.G.S., etc.

The author referred to a fossil skull from the Triassic sandstone of South Africa, which combined dental characters resembling those of a carnivorous Mammal with the cranial structure of a Saurian. The structure was described and figured in Owen's 'Catalogue of the Fossil Reptilia of South Africa,' under the generic title of *Galesaurus*, as belonging to a distinct suborder of Reptilia, termed *Theriodontia*.

The characters of the skull and teeth of the original specimen of *Galesaurus* have been brought to light by further development.

In both the type specimen and that lately received the reptilian nature of the fossil is indicated by the single occipital condyle and other features. The chief difference from a mature male of a placental or marsupial carnivore is the evidence of a primordial "gullet-tract." Further details as to the structure of the skull were given, more especially with reference to the orbits and nasals. The palatal region repeats the same general characters as in previously described Theriodonts. The angle of the jaw is not produced, as in the Crocodile, beyond the articular element. In general shape and bony strength the mandible of *Galesaurus* resembles that of a mammal.

The dentition is so much better preserved in the new specimen than in the type Galesaur as to call for description and illustration. In four of the upper molars the entire crown is preserved; it shows less length and greater breadth than appears in the previous restoration, is moderately curved externally, and triangular; the base is flanked by a short cusp before and behind, and the corresponding margins are finely crenulate, as in the molars of *Cynodracon*. The incisors are eight in number in both upper and lower jaws, four in each premaxillary, opposed or partially interlocking with the same number in each mandibular ramus; they have longish, slender, simple-pointed crowns. The canines, one on each side of both upper and lower jaws, have the same laniariform shape and size of crown as in the original fossil. In the right maxillary bone the long deeply planted root is exposed; the corresponding part of the lower canine is similarly exposed in the left mandibular ramus. No trace of successional teeth, as in ordinary Saurians, has been found.

Both Crocodiles and Alligators have two or more teeth of canine proportions; but the author shows how they differ from those of mammalian

carnivores and *Galesaurus*. A similar character and disposition of destructive canines is shown by the fossil jaws of the Oolitic great extinct carnivorous Saurians, e.g. *Megalosaurus*. In the Triassic Labyrinthodonts the destructive and prehensile laniaries would by position rank as incisors rather than canines. In existing Lizards the dental series has more uniformity, and the cement-clad roots contract bony union with the jaw-bone. In *Galesaurus* the teeth, besides being distinguished, as in Mammals, by their differential characters, are implanted freely in sockets, the cold-blooded character being chiefly manifested in the greater number of teeth following the canines, and in their want of distinction.

Lastly, the author remarked on the earlier reptilian character shown by the Oolitic Mammal *Amphitherium*, and also by the existing Australian *Myrmecobius*. He speculates on the degree of resemblance manifested by the teeth of the old Triassic Reptile of South Africa with the exceptional characters of some of the low Australian forms of Mammals.

2. "The Cetacea of the Suffolk Crag." By R. Lydekker, Esq., B.A., F.G.S., etc.

This paper commenced with notices of previous contributions to the subject by Sir R. Owen, Prof. Ray Lankester, Prof. Huxley, and Prof. Flower. In the preparation of a catalogue of the specimens in the British Museum, the author had had occasion to examine the collection of Cetacea from the Crag, not only in that Museum, but also in the Museum of Practical Geology, that of the Royal College of Surgeons, and in the Ipswich Museum, besides visiting the collections at Brussels. In consequence several additions to the fauna and also numerous emendations of specific names were noticed in the paper now laid before the Society. Prof. Ray Lankester's views as to the Diestian affinities of the English-Crag Cetacea were confirmed by this comparison.

Detailed notes on the specimens examined and the species identified were given. The following list of the species believed to be represented in the various collections mentioned was given at the conclusion of the paper:—

BALÆNIDÆ.

Balæna affinis, Owen.
,, *primigenia*, van Beneden.
,, *insignis* (van Beneden).
,, *balænopsis* (van Beneden).
Megaptera affinis, van Beneden.
,, *similis* (van Beneden).
,, *minutus* (van Beneden).
Balænoptera definita (Owen).
,, *Goropi*, van Beneden.
Balænoptera borealina, van Beneden.
,, *emarginata* (Owen).
Cetotherium Brialmonti (van Beneden).
,, *dubium* (van Beneden).
,, *Hupschi* (van Beneden).
,, *brevifrons* (van Beneden).
Herpetocetus scaldiensis (van Beneden).

PHYSETERIDÆ.

Eucetus amblyodon, du Bus.
Homocetus Villersi, du Bus.
Balænodon physaloides, Owen.
Physodon grandis (du Bus).
,, *fusiformis ?* (du Bus).
Hoplocetus crassidens, Gervais.
,, *borgehoutensis*, Gervais.
,, *crassidens ?* Gervais.
Hyperoodon, sp.
Choneziphius planirostris (Cuvier).
Choneziphius planus (Owen).
,, *Packardi*, Lankester.
Mesoplodon longirostris (Cuvier).
,, *tenuirostris* (Owen).
,, *gibbus* (Owen).
,, *angustus* (Owen).
,, *angulatus* (Owen).
,, *compressus* (Huxley).
Floweri, Canham MS.

SQUALODONTIDÆ.

Squalodon antverpiensis, van Beneden.

DELPHINIDÆ.

Orca citoniensis, Capellini.
Globicephalus uncidens (Lankester).
Delphinoid genus, *non det.*

3. "On a Jaw of *Hyotherium* from the Pliocene of India." By R. Lydekker, Esq., B.A., F.G.S., etc.

Colonel Watson, the Political Resident in Kattiawar, had recently sent to the author a fragment of a left maxilla with the three true molars from Perim Island, in the Gulf of Cambay. The specimen belonged to *Hyotherium*, and apparently to an undescribed species, the differences between which and the several forms previously known from various European and Asiatic beds, were pointed out. The author also called attention to the peculiar association of types found in the beds of Perim Island, and to the affinities of the genus *Hyotherium* with the recent *Sus* and *Dicotyles* on the one hand, and with the Upper Eocene *Chœropotamus* on the other.

CORRESPONDENCE.

THE FACETTED BLOCKS FROM THE PUNJAB SALT RANGE.

SIR,—Had I been aware that the abstract of my remarks "On a Smoothed and Striated Boulder from a Pretertiary Deposit in the Punjab Salt Range" would appear in the GEOLOGICAL MAGAZINE, together with Mr. Wynne's notes on another facetted fragment from the same bed, I would have asked permission to add a few observations.

The great difficulty in accounting for the origin of these facetted blocks is that whilst the smoothed surfaces are in every respect similar to those on stones worn by glacial action, no fragments from moraines, from boulder-clay, or from other glacial deposits are known to exhibit the peculiar facetting characteristic of the present specimens. I have heard of something similar, but have not seen an example. Other geologists who have a wide experience of smoothed and striated boulders are equally puzzled.

At the British Association meeting two suggestions were offered as to the cause of the markings—the first was soil cap action; this, however, could not have produced the facets, nor, unless it acted in two or more directions at the same time, could it have caused the striation. The other suggestion was wind and sand action, by which similarly facetted blocks are said to have been produced in Australia. My objections to this view are that wind and sand action never, so far as I have seen, produce plane surfaces, that the striation (or rather grooving) on wind-worn surfaces is of a different character, and that the wind-worn fragments sent from New Zealand by Mr. Enys, and figured in the Quart. Journ. Geol. Soc. for 1878 (xxxiv. p. 86), as well as some described in the American Naturalist (occurring, I think, in Maine), have no resemblance to the Punjab specimens. Further and very cogent arguments are supplied by Mr. Oldham in a paper which I trust will shortly be published in this MAGAZINE.

Before concluding, may I point out that felspar-porphyry on p. 494 is a misprint for felsite-porphyry.

Nov. 8th, 1886. W. T. BLANFORD.

THE FOLIATION OF THE LIZARD GABBRO.

Sir,—Students of petrology will, I am sure, feel indebted to my friend Mr. Teall, no less for his valuable paper on the Lizard Gabbro than for the admirable Plate with which it is illustrated. He has stated very clearly the reasons in favour of ascribing the peculiar rock-structure, there described and depicted, directly or indirectly to mechanical influences. In this it is quite possible he may be right. But, inasmuch as there seems to me some danger at the present time of overestimating the part played by mechanical agencies in producing the crystalline schists—a part which hitherto undoubtedly has been much underestimated—a danger in short of supposing that *a* truth is "*the* truth, the whole truth, and nothing but the truth," I venture to put a few words on record, not so much by way of protest or criticism, as for the purpose of showing that in Mr. Teall's proposed solution of this puzzle there are difficulties on which he does not dwell, so that it ought at present to be regarded as an hypothesis on its probation, and should not be quoted (as I feel sure it would otherwise be) as an undoubted fact. My remarks, be it understood, must be regarded as directed, not against the general principle, of which this Lizard gabbro would be a particular case, but against the application of the principle to this case.

The difficulties which I feel may be thus stated. If the foliation of the Lizard gabbro is the result of earth-movements acting on the rock after it became solid, these movements, having resulted in effects of an exceptional character, should have been of exceptional importance—that is to say, the whole district should bear the impress of the same earth-movement that has foliated the gabbro. Mr. Teall states indeed: "that the Lizard district has been profoundly affected by earth movements is apparent on every hand." Speaking for myself, I should prefer to read 'considerably' for 'profoundly,' so far as regards the earth-movements to which we could ascribe the foliation of the gabbro. I am well acquainted with three large separate areas of country which have been 'profoundly affected by earth-movements' since their rocks became solid, and I do not find a parallel to them in the Lizard, except perhaps at the extreme south and near the great boundary fault on the north. There are undoubtedly numerous dislocations (as I have pointed out in one of my papers on the district); there are endless wrenches, slips and nips; but there are few signs of a great compression such as may often be traced through whole regions of crystalline rock almost as surely (when the key to it is once found) as a slaty cleavage in one of sedimentary rock. This foliation of the Lizzard Gabbro, as Mr. Teall truly says, comes in and disappears, even in the thin veins, in apparently the most arbitrary manner. This of course is perplexing in any theory of its origin. I only quote it to show that our difficulties are so far not diminished by the new one. Again, the foliation often occurs where the neighbouring rocks show little or no signs of material disturbance. I do not say that the contrary is not sometimes the case, but near the Balk (or Pen Voose), and to the north

of Karakclews, and at Coverack this is the case. Serpentine is a decidedly brittle rock. Any one who knows the Alps is familiar with its pressure-modifications. Yet the serpentine at all these three places, as a rule, is singularly perfect in its structure, free from all indications of serious mechanical disturbance. There are, I am well aware, serpentines at the Lizard which might be quoted as evidencing 'pressure-structure,' but, as it happens, these do not occur at any one of the three localities where the foliated gabbros exist. At all three the serpentines are perfectly normal in their characters. But it might be asserted that, at the epoch of the pressure, the serpentine existed as a peridotite, and this very possibly would be true; still I think I know what is the effect of pressure on a peridotite, and could conjecture what the results would be when it was converted into a serpentine, and of these also I find no signs at the above-named places.

But it may be argued that this foliation in the gabbro is the result not so much of a general compression of the district, as of local strains, thrusting, and shearing in the gabbro-mass itself, due to local disturbances; that it is a structure resulting from *faulting* rather than from *folding*—from dislocation-strains rather than compression-thrusts. So far as the minor cases at the Balk and Coverack are concerned, this explanation would seem feasible, but it is difficult to apply it to such an enormous mass as that of Karakclews, where the differentiation and parallel ordering of the minerals have an extraordinary development. Moreover, as Mr. Teall justly says, this mass sends out veins into the neighbouring serpentine, and that rock to the north has been repeatedly pierced by small gabbro veins, so that we cannot suppose the main mass to have been thrust far away from its original position.

There are then, as it seems to me, some serious difficulties in applying the theory of pressure-foliation to the Lizard gabbros, if it be assumed that the structure was produced in a solid rock. Mr. Teall's solution of the difficulty *may* be the right one, but it is always well to look at all sides of a question. A new answer to one of Nature's greater riddles is often rather a first approximation to the truth, than the actual truth, and stands in need of subsequent modification. As at present advised, I am disposed to think this the case in regard to the Lizard gabbro, though further study may remove my difficulties. Still I think we shall do well to proceed cautiously in regard to this new hypothesis of pressure-metamorphism. It has come to many, like myself, almost as a revelation, pouring a flood of light upon a number of dark enigmas; but for all that we must not allow it to dazzle our eyes. In this, as in so many other things, reason should go hand in hand with faith. T. G. Bonney.

Necrology.—We have to record with deep regret the recent losses by death of Dr. H. Abich, F.M.G.S. (Vienna); Mr. George Busk, F.R.S., F.G.S.; Rev. W. Downes, B.A., F.G.S.; the Earl of Enniskillen, D.C.L., F.R.S., F.G.S.; Mr. Caleb Evans, F.G.S.; and Prof. F. Guthrie, F.R.S., F.G.S.

Erratum.—Geol. Mag. November Number, p. 492, line 10, delete "difficult."

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